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# AERIAL

# WIRE ROPE-WAYS

## Their Construction and Management

BY

A. J. WALLIS-TAYLER, A.M.I.C.E.

AUTHOR OF "REFRIGERATION, COLD STORAGE, AND ICE-MAKING," "THE POCKET BOOK OF REFRIGERATION AND ICE-MAKING," "TEA MACHINERY AND TEA FACTORIES," "SUGAR MACHINERY," "MOTOR VEHICLES FOR BUSINESS PURPOSES," "THE PRESERVATION OF WOOD," ETC., ETC.

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# PREFACE

SOME years ago the author wrote a book entitled "Aerial or Wire-Rope Tramways," which is now out of print. Since the publication of that work the term tramway used in relation to aerial lines has been found by manufacturers and others to be somewhat misleading, and these installations have become almost universally known as aerial or wire rope-ways. In consequence of this it has been deemed advisable in this new work to discard the term "Tramway" and substitute that of "Rope-Way" in order to conform with the present terminology.

The new book has been practically rewritten, and those portions of the original work used have been thoroughly revised and brought up to date. Considerable additions to the subject matter, together with a number of illustrations, have been made in the chapters devoted to Details of Construction, Electrically Driven Wire Rope-Ways, and that on Miscellaneous Information. A number of descriptions and illustrations of installations of lines on the different systems are given by way of example as in the former work. Much out-of-date matter has been eliminated and replaced by particulars and illustrations of lines of recent construction. Additional matter and examples of lines on the telpher system are also given. A special chapter is devoted to wire rope-ways for hoisting and conveying and for coaling vessels at sea, the former type of rope-way being of great utility in building bridges, making canal, railway and other excavations, for dredging work, and for other purposes too numerous to mention; and the latter being a subject of no small interest and importance especially with relation to warships when engaged in hostilities.

In the chapter dealing with miscellaneous information will be found a method of calculating the strains on the carrying rope of an aerial rope-way, also hints as to the splicing, securing, preserving, &c., of wire ropes. An addenda to this chapter devoted to general matters gives instructions (illustrated) for uncoiling wire ropes, removing kinks, estimating for wire rope-ways, approximate prices for wire rope-ways of different capacities, and a number of useful tables. The book is provided with a sufficient Index, a Table of Contents, and a List of Illustrations.

It is hoped that the present work will be found of considerable more service than the former one by those desirous of obtaining information regarding aerial or wire rope-ways.

A. J. WALLIS-TAYLER.

SUTTON, SURREY.

# CONTENTS

## CHAPTER I



## CHAPTER II



## CHAPTER III



## CHAPTER IV

# ILLUSTRATIONS

# AERIAL OR WIRE ROPE-WAYS

## CHAPTER I

INTRODUCTORY—DIFFERENT SYSTEMS OF AERIAL OR WIRE ROPE-WAYS—THE RUNNING OR ENDLESS ROPE SYSTEM—THE FIXED CARRYING-ROPE SYSTEM.

### Introductory.

OVER fifteen hundred years ago wire ropes were known to the Chinese, and were employed as rope-ways for crossing rivers. It is also on record that aerial rope-ways were used in the Middle Ages for the transmission of goods. A book in the library at Vienna dated 1411 shows a drawing of a rope-way, and according to the Danzig "Chronicles" one Wybe Adam, a Dutch engineer, constructed an aerial rope-way in that town in the year 1644.

The advantages possessed by aerial or wire rope-ways—especially in mountainous countries—for the handling of materials, have now become so well understood that it is unnecessary to expatiate upon them. The system can likewise, though to a lesser extent, be usefully employed for passenger traffic.

Amongst the more obvious general advantages the following may be cited:—

The unavoidable heavy outlay that would be entailed in a hilly country by the necessity of making tunnels, cuttings, and embankments for a line of railway is avoided; and an aerial or wire rope-way can be constructed and worked on hilly ground at a cost not greatly exceeding that which would be called for on a level country. Rivers and ravines can be spanned without the aid of bridges. Gradients quite impracticable to ordinary railroads can be worked with ease. The lines do not occupy any material quantity of ground, a post or standard at wide intervals being sufficient to carry them, and the intervening land being left free for cultivation or other use. The cost of a line is in all cases in strict accordance with its working capacity. Floods or heavy snows do not interfere with the working. A line can be moved from one place to another with comparative facility. And finally, power can be taken off at any point along the line and utilised for driving machinery.

The principal applications of wire rope-ways have been already mentioned in the Preface. Of these, that to the working of mines is one of considerable importance, and in this connection the advantages derived from the use of a wire rope-way arranged to both hoist and convey, for open pit mining—such as described under the head of Wire Rope-Ways for Hoisting and Conveying—cannot be over-estimated. The superiority of open pit mining is well known, it saves the great outlay otherwise required for timbering, shaft sinking, pumping, ore breaking, and the extra cost of blasting, and with an aerial or wire rope-way, the opening can usually be spanned, and the waste carried back to a hollow, thus admitting of the over-burden being delivered directly to its dumping ground. Where the pit is not deep some method of working with an incline railway is frequently used, but no matter how the latter may be laid down, a certain amount of ore will be covered, and, moreover, the tracks will have to be constantly cleared of material thrown on them by blasting operations. The cost of loading the railway waggons is besides far higher than that of the shallow skips or carrier buckets of an aerial rope-way.

In placer mining, the greatest difficulty experienced is the handling of the earth deposits in the river beds and streams, so as to work them to such a depth as to get at the richest deposits, which lie near the bed rock. This has been successfully performed by means of an arrangement of aerial or wire rope-way on the hoisting and conveying principle, working with special forms of self-filling grab buckets, or of drag buckets.

Aerial or wire rope-ways have been also advantageously used for stripping coal mines.

Another use to which wire rope-ways can be very profitably applied is the carriage or removal of produce from land. The most desirable of these applications are perhaps those on sugar plantations for the delivery of the canes to the crushing mills, and on farms for the carriage of beetroot to the sugar factories, especially the former, where the low prices, due to the competition of beet sugar, renders the adoption of every possible labour-saving contrivance an absolute necessity.

An important feature connected with the use of aerial or wire rope-ways for the above purpose, is that the crops can be removed from the land by their means without in any way injuring the latter. In the case of sugar plantations, moreover, the uneven nature of the ground is frequently such as to render the laying down of lines of railway from the cane pieces to the works a matter of great difficulty, if not a total impossibility, and such lines in any case demand the erection of a greater or lesser number of bridges, are expensive both in first outlay and in maintenance, and take up and waste a considerable amount of land. On the other hand, where no railway or tramway is laid down, the saving effected by the use of an aerial or wire rope-way as compared with cartage by mules, horses, and oxen, and the roads and traces and consequent waste of land, and cost of maintenance, would be even more marked. In such cases, indeed, the value of a wire rope-way is very great, and that this fact is recognised by owners of large estates is evidenced by the many installations now to be found, not only in Demerara, where they have been in successful operation for a number of years past, but also in Jamaica, where many have inclines as steep as 1 in 3, Mauritius, Martinique, St Kitts, Guatemala, Australia, and elsewhere.*

In almost every description of factory a short rope-way or cable-way could be used with advantage, and installations of wire rope-ways are now in use in numerous places for connecting the different departments of factories which are situated at too wide a distance apart to allow of being spanned by a bridge, or where the intermediate space is occupied by buildings, water, roadways, &c., which have to be passed over. Such cases admit of a considerable saving of expense being effected by the use of wire rope-ways, which latter do away with the necessity of lowering goods from the upper stories of works to the ground, and the subsequent removal of these goods by a circuitous route to, and elevation to a higher level at their destination.

In factory lines the ropes can be frequently supported at many points from brackets fixed to the walls of adjacent buildings, thus effecting a saving of the

* See pages 128-135.

posts or standards that would otherwise be required; and the necessary driving power, moreover, can usually be obtained from the shafting of the works.

At the present time short cable-ways or wire rope-ways are in operation at most of the up-to-date print works, and similar factories, in Lancashire,* also in dye works, manure works, chemical works, linoleum works, brick works, mills, and other factories too numerous to mention.

Wire rope-ways provide both cheap and advantageous means of forming piers for loading and discharging minerals, and other materials, from ships and lighters, which in certain situations are forced by the shallowness of the water to lie at some distance from the shore. In the case of a cable-way or wire rope-way, instead of the long row of piles that would otherwise be necessary, all that will be required to connect the shore with a point at deep water to which the goods can be brought by barges or ships, are a few posts or standards fixed in the bottom and rising to a height of about 12 feet above the water, and which posts may be placed at wide intervals (180 feet or more) apart, a small group being provided at the deep-water point to which the terminal can be fixed. The motion of the wire rope can also be used for driving cranes at the terminal points, as well as for carrying loads to or from the shore, thus admitting of the engine being located in a secure position on the shore where it may be protected from damage through storms, and, besides, permitting of the cranes being run at so high a speed as to enable barges to be safely discharged when rising and falling from the effects of a heavy sea.

Numerous installations of this description are in

* See pages 125.

successful operation, such an arrangement being used at the end of the wire rope-way at the Cape de Verde Islands, at Russel, Bay of Islands, New Zealand, &c., which installations will, in a succeeding chapter, be found briefly described and illustrated.*

## Different Systems of Aerial or Wire Rope-Ways.

Wire rope-ways may be conveniently divided into two main or principal classes, viz., first, that wherein a running or travelling endless rope supporting and moving the carriers is employed; and, secondly, that wherein a fixed carrying rope and a light running or travelling hauling rope attached to the carriers, by couplings or grips is used. In the latter case two fixed carrying ropes are sometimes used.

These two main classes are further subdivided by W. T. H. Carrington, M.I.C.E., a well-known authority upon the subject, in his practice into five different systems or arrangements, viz.:—The endless running rope with the carriers detachably connected to the rope by means of saddles; the endless running rope with the carriers rigidly fixed in position upon the rope; the double fixed rope type with carriers mounted on trucks or runners and detachably secured at predetermined intervals to an endless hauling rope; the single fixed rope type with one carrier drawn from one terminus to the other and *vice versâ* by means of an endless hauling rope; and, finally, two fixed carrying ropes with an endless hauling rope by which one carrier is drawn in one direction upon one carrying rope, whilst another carrier is drawn in the opposite direction upon the other carrying rope.

*See pages 112-116.

When erecting a wire rope-way it is imperative to carefully select such an arrangement as will be best suited to the requirements of the situation. The failures sometimes recorded are generally due to makers insisting upon an universal application of one particular type.

## The Running or Endless Rope System.

This system, which is by far the most simple, was invented by C. Hodgson about the year 1868. It is capable of advantageous application wherever the amount of material to be carried does not surpass 500 tons per working day of ten hours, and the individual loads 6 cwt. The inclines, moreover, should not be steeper than 1 in 3, and the section of the ground should not necessitate a longer span than 600 feet.

The endless running-rope type of rope-way consists shortly of an endless wire rope, supported upon a series of pulleys mounted upon strong posts or standards located some 200 feet apart, but with occasional spans of three times that distance, the rope passing at one end of the line round an arrangement of driving gear comprising a 6 or 10 feet diameter drum rotated by steam or other power at a speed of about three miles per hour, and at the other end round a similar wheel or drum provided with tightening gear. The loads are carried in boxes or receptacles hung on the rope (by means of V-shaped saddles) at the loading end, the arrangement being such as to maintain the receptacles and their contents in a state of perfect equilibrium, whilst at the same time admitting of their passing the supporting pulleys.

But one endless running rope is employed, which, it will be seen, forms both the carrying and hauling rope for the buckets. This system has been improved from time to time, both by its original inventor and also by Hallidie, Carrington, and others; but although apparently so simple, and decidedly the cheapest plan, its successful working is a matter in many instances of so much difficulty that it is being to a great extent superseded by the fixed-rope system. It is still, however, pretty extensively used in Northern Spain and America.

The modified arrangement of the running or endless rope system previously mentioned admits of steeper inclines being worked, indeed it may be said that no limit exists to the gradient that can be successfully negotiated. This type of line is specially suitable where sudden and continual changes of level occur, guard or depressing pulleys being easily placed where requisite without interfering with the passage of the carriers, so that the vertical angle of the line can be altered at each support or standard. The driving and tightening gear and endless rope are arranged practically as before, but instead of the carrier saddles riding on the rope and being retained in place by friction, they are rigidly secured by a steel band or clip, or other arrangement, so that they are fixed in position and must follow the rope, passing round the wheels at the terminals, instead of running on to shunt rails as in the former case. For this reason the driving wheel is usually arranged in the form of a special clip-drum, and the tightening wheel is so formed as to allow the carriers to pass round it with ease. The carrier receptacles are as a rule unloaded by striking a catch so as to either cause the bottom to open or the whole receptacle to capsize or tip up.

The average cost per ton per mile for transport on the running or endless rope system, including renewals of parts and labour but not fuel, varies from threepence to fivepence per ton.

## The Fixed Carrying-Rope System.

This system was also devised by Hodgson, and improved by Bleichert, Otto, Carrington, and others. It comprises one or two fixed ropes and a corresponding number of light hauling ropes. This plan admits of very wide spans being made without support, and a valley, river, or ravine of 3,000 feet and upwards can be negotiated with ease. Wherever a sufficient fall occurs, and it is required to transport goods or material from the higher to the lower ground, the power of gravity due to the loads can be utilised in the case of a double fixed carrying-rope line to raise the empty receptacles, and the line worked practically as a self-acting incline. When, on the contrary, the loads are required to ascend, or the line is practically level, or in the case of a single fixed carrying-rope line, motive power must be provided. A small amount of this, however, will only be requisite for working a line on this system, as the rolling load gives rise to but little friction.

As above mentioned, aerial rope-ways of the fixed-rope type are subdivisible into three classes. The first, or that in which two parallel fixed ropes are used, upon which carriers are arranged to run, and are drawn along by means of a hauling rope, forms a desirable arrangement in situations where over 500 tons of material have to be transported per day, and where the individual loads surpass 6 cwt. The inclines may exceed 1 in 2, and the spans 1,000 feet.

It may be here mentioned, however, that the capacity of transport by the former system may be indefinitely increased by grouping the lines where the situation admits of it, an arrangement which obviously possesses the advantage of practically perfect immunity from complete stoppage from breakdown.

Briefly, this type of rope-way consists of two fixed carrying ropes stretched parallel to each other about 7 feet apart, and supported by posts or standards located about 300 feet apart, upon suitable saddle castings. The carrying ropes are anchored at one of the terminals, and are provided at the other with some suitable form of tightening gear. The carrier-travellers or trucks, which are fitted with steel-grooved wheels to fit the ropes, run upon the latter, the receptacles being suspended from these travellers by means of frames or hangers. The carriers are connected by some suitable form of friction or of locking grips or couplings to an endless hauling rope operated by driving gear at one end, and provided with tightening gear at the other end, the usual rate of speed being from 4 to 6 miles per hour. On arrival at a terminal, the grips or couplings are automatically released, and the carrier-traveller runs upon a shunt rail.

This type of wire rope-way is economical in wear and tear, but somewhat expensive in first cost, and is unsuitable where there are sudden changes in the vertical angle of the line.

The second type of fixed rope-way, wherein a single fixed rope and one carrier are used, is the best suited for situations where only moderate quantities of materials have to be carried, the individual loads being heavy, and the spans long, and the inclines steep.

The arrangement consists of a single fixed carrying rope upon which a single carrier is mounted through its traveller or truck, and is drawn forward and backward by means of an endless hauling rope operated by suitable reversible driving gear at one end, and having tightening gear at the other. The fixed carrying rope is supported on posts or standards placed at intervals of about 300 feet apart, the hauling rope being carried on pulleys fitted with guide bars located in the centre of the standard over which the carrier passes, the standards being so constructed as to admit of the carrier passing through them. The return portion of the hauling rope is carried upon outside pulleys mounted upon brackets or arms on the standards. The attachment of the hauling rope to the carrier head is made by a pendant so shaped as to admit of its passing under the saddle-transom.

This type of wire rope-way is cheaper in both first cost and maintenance than that just described, and it is likewise simpler to erect and to work.

The third type of fixed rope-way, in which two fixed carrying ropes and two carriers are employed, the one moving upon one carrying rope whilst the other moves down upon the other and *vice versâ*, is applicable where the spans are of extreme lengths, and the individual loads very heavy.

The two fixed carrying ropes are stretched side by side as in the other double fixed carrying-rope type of rope-way, but only two carriers are used, and most frequently these lines are arranged to operate as self-acting inclines, the loaded carrier descending and hauling up the empty carrier, or lighter loaded carrier, which in turn is loaded and descends. When the loaded carrier passes up, and the empty or light carrier descends, power is used. The travelling speed may be as high as 30 or 40 miles an hour. The individual loads may be of 3 tons or more, and spans of over 3,000 feet can be traversed. A line in the Pyrenees was constructed and operated successfully with a span of 4,500 feet between the supports.

This type of line is cheaper than the other arrangement of two parallel fixed carrying ropes, in first cost, and also in maintenance, and fewer hands are required to work it. The quantity of material it is capable of transporting per day is, of course, less, and the speed of running produces a rapid wear of the rope.

## CHAPTER II

DETAILS OF CONSTRUCTION: POSTS OR STANDARDS—WIRE ROPES OR LINES FOR RUNNING-ROPE SYSTEM—CARRIER BOXES OR SADDLES FOR THE RUNNING-ROPE SYSTEM—WIRE ROPES OR LINES FOR THE FIXED CARRYING-ROPE SYSTEM—CARRIER TRUCKS, OR RUNNERS, FOR THE FIXED CARRYING-ROPE SYSTEM—FRICTION GRIPS OR COUPLINGS—KNOTS OR CARRIER COLLARS FOR LOCKING GRIPS OR COUPLINGS—PAWL LOCKING GRIPS OR COUPLINGS—CLAW LOCKING GRIPS OR COUPLINGS—CARRIER RECEPTACLES OR VEHICLES—MOTIVE POWER.

As in the case of railways or tramways, aerial or wire rope-ways consist essentially of three all-important parts, viz., the line or track, which in this case takes the form of a running or travelling, or of one or more fixed, wire ropes or cables, in accordance with the system in use; the carriers, vehicles, or cars for the goods or passengers; and finally, of the motive power for the line.

### Posts or Standards.

Whether the line be constructed on the running or travelling, or fixed carrying-rope or cable system, the rope or cable must be suitably supported at proper intervals upon wooden or iron posts or standards. These posts are usually placed at from 100 feet to 300 feet apart, the exact distance depending of course upon the configuration of the ground to be passed over, an accurate survey and section of which should be always executed. When, however, a gorge, ravine, narrow valley, or river has to be crossed over, the distance between the uprights or supports may be very considerably increased, and, as has been already mentioned, spans of 3,000 feet, or, in extreme cases, even considerably more,* may be safely resorted to.

The survey for a line of wire-rope way should in all cases be carefully executed. And it is important to bear in mind that wherever it is possible the rope-

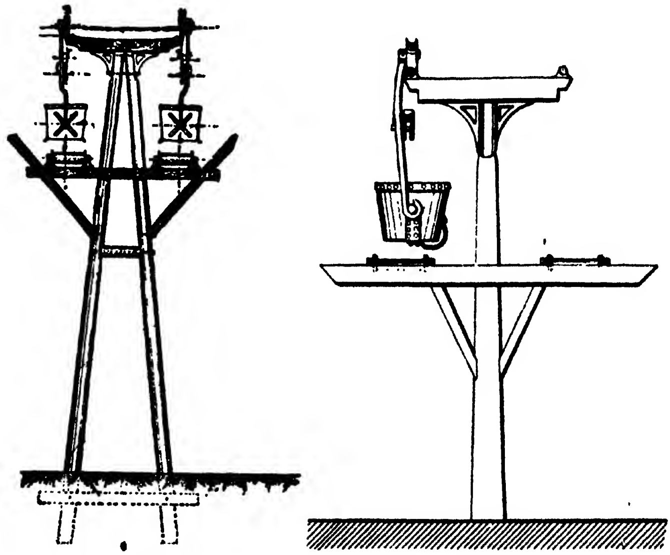


FIG. 1. FIG. 2.

FIGS. 1 and 2.—Wooden Posts or Standards.

way should be straight, as each angle will render necessary the erection of a complete station, thus increasing both the cost of construction and that of working. At each point where a post or standard is to be erected, the depth of solid ground should be ascertained.

The posts or standards when constructed wholly or

* See page 12.

mostly of wood may, in the simplest cases, consist of common round poles or spars forming the legs, and having top cross-pieces of well-seasoned oak or equivalent timber. These legs are stayed near their lower extremities, and should be let into the ground for a sufficient distance to ensure the requisite rigidity.

Two simple forms of wooden standards or posts are illustrated in Figs. 1 and 2.

Upon the upper ends of the posts are cross-pieces secured in position by iron brackets, and provided with suitable shoes, saddles, or seats to receive the carrying wire ropes, two of which are used in both these instances to form double lines. Lower crossbars braced to the posts carry rollers, which serve to support the driving or hauling ropes at such times as the latter are not engaged by passing carriers or vehicles.

Figs. 3 and 4 show in front and side elevation a simple design of wooden standard with four legs not to exceed 20 feet in height. The timber required for a standard of this pattern 20 feet high, according to American (Leschen's) practice, is as follows:—One top cap, 6 in. by 8 in. by 8 ft. 6 in.; one sheave girt, 6 in. by 6 in. by 7 ft. 7 in.; two braces, 4 in. by 6 in. by 5 ft. 6 in.; two posts, 8 in. by 8 in. by 20 ft.; two braces, 6 in. by 6 in. by 18 ft.; one sill, 8 in. by 8 in. by 12 ft.; one anchor sill, 6 in. by 8 in. by 6 ft.

Figs. 5 and 6 are similar views of a 40-foot standard, the requisite timber being:—Eight pieces, 6 in. by 6 in. by 22 ft.; one piece, 6 in. by 8 in. by 8 ft 6 in.; two pieces, 8 in. by 10 in. by 12 ft.; three pieces, 6 in. by 6 in. by 16 ft.; two pieces, 4 in. by 6 in. by 12 ft.; eight pieces, 2 in. by 8 in. by 14 ft.; eight pieces, 2 in. by 6 in. by 14 ft.; eight pieces, 2 in. by 8 in. by

FIG. 4.

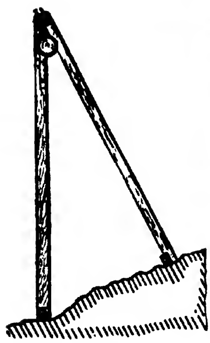
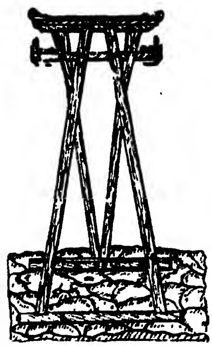


FIG. 3.



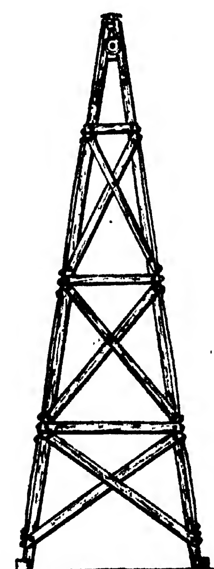


FIG. 6.

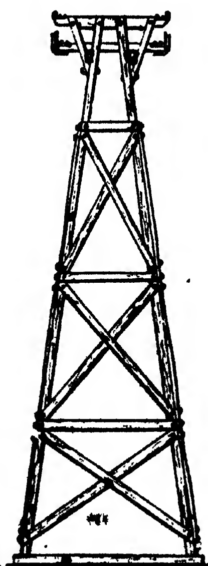


FIG. 5.

FIGS. 3 and 4 and FIGS. 5 and 6.—Wooden Standards, not to Exceed 20 ft. in Height and 40 ft. in Height.

12 ft.; twelve pieces, 2 in. by 6 in. by 12 ft. The side pieces are in this standard strengthened with iron plates as shown in the drawing.

The dimensions given above are all in sawed material, but where poles are procurable along the route they may be substituted for the latter and the cost of construction be reduced. Fig. 7 shows a wooden standard with six legs.

When iron is employed as a material for the sup-

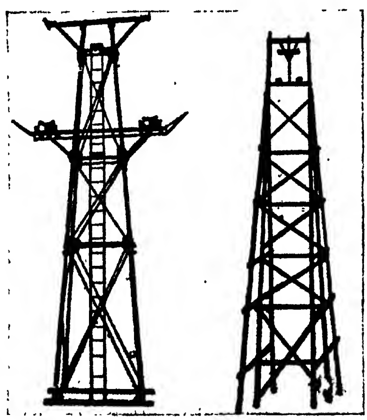


FIG. 8. FIG. 7.

FIGS. 7 and 8.—Wooden Standard with Six Legs, and Iron Standard with Ladder Affording Access to Head.

ports, channel or I-beams, with angle-iron stiffeners, and channel iron cross-pieces, are usually employed. Where the loads are heavy and the spans considerable, the posts or standards should be constructed with four legs.

The design of these supports, whether constructed of timber or iron, will vary from those of great simplicity, required for short lines carried at no great height above the ground level, to structures of comparative complexity in the case of the more important installations.

One pattern of iron standard fitted with an iron ladder giving access to the head is shown in Fig. 8. Another pattern is illustrated in Fig. 9.

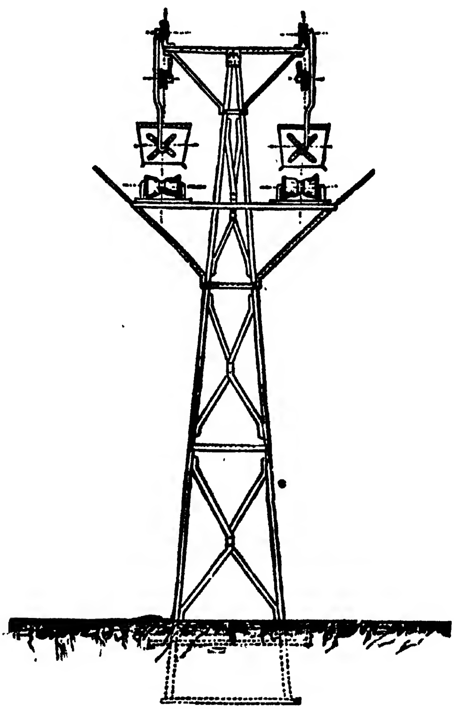


FIG. 9.—Iron Post or Standard.

Another type consists of wrought-iron pipes connected by ferrules, which can readily be taken to pieces, and can be adjusted as regards height by sliding or telescoping the one length of pipe within the other.

The standards or supports, of whatever form of construction they may be, when above 45 or 50 feet in height, are usually stayed with wire guy ropes as an additional security. When intended for supporting running ropes, the seats or saddles are replaced by sheaves or pulleys.

Descriptions and illustrations of a number of other posts or standards will be found given later on in the chapters devoted to the particulars of various installations that have been erected in different parts of the world.

## Wire Ropes or Lines for Running-Rope System.

As regards the line or track itself, the characteristic features of the wire ropes used for this purpose, in both the above systems, will be found dealt with to a certain extent in the above-mentioned descriptions of the various installations on both plans. Inasmuch, however, as such ropes form a very, if not the most, important part of aerial or wire rope-ways, being both the chief wearing parts and those most costly to renew, a few preliminary general observations upon the classes of wire rope most suitable for the purpose in question will be of interest. The methods employed for the splicing and securing of the ropes, and for their preservative treatment, will be found dealt with in the last chapter of the book. Even the briefest description of the manufacture of wire, a subject intimately connected with wire ropes, is beyond the scope of this work, but those desirous of obtaining full information upon this matter can do so by perusing a very interesting work by J. Bucknall Smith, C.E.*

For a wire rope-way of the main class first men-

* "Wire: its Manufacture and Uses," by J. Bucknall Smith, C.E., Offices of *Engineering*.

tioned, where a running or travelling endless rope carrying the buckets or carriers is used, this rope should preferably be of what is known as the Albert or Lang* lay, that is, a rope in which the component wires of the strands, and the strands themselves, are laid in the same direction.

Figs. 10 and 11 are photographic reproductions showing a wire rope of this description as it appeared respectively when new, and after two years' use, on a wire rope-way on Carrington's system erected between Badovalle and Ortuella in Spain. This rope was put to work at the beginning of July 1893, and was kept in continual use until 20th July 1895, at which time it had carried upwards of 165,000 tons of iron ore, the cost for rope renewal being in this instance only about one-fourth of a penny per ton mile. It was, however, far from being worn out when removed, as was proved by the fact that the breaking strain was even then found to be 27½ tons, against one of 29$\frac{1}{20}$ tons when new. This was a very remarkable performance, and bore abundant testimony to the quality of the

FIG. 10.—Wire Rope, Albert Lay: Appearance when New.

FIG. 11.—Wire Rope, Albert Lay: Appearance after Use on Wire Rope-Way.

* A so-called patent was acquired in this country in the year 1879 by J. Lang for a wire rope constructed on the principle invented by Professor Albert of Clausthal about the year 1837, and which at the time of Lang's patent had been in common use in Germany for over forty years, and had been made public in England for at least ten years.

material employed, and the care and skill exerted in its manufacture by the makers.* It also shows how desirable it is from an economical point of view to use only ropes of the very best quality obtainable, although they may primarily entail a larger outlay.

Both the above and many other practical tests very conclusively prove that the Albert or Lang lay is decidedly the most suitable form of construction for running ropes.

The endless running or travelling rope, which should be made of special steel, usually passes at one end or terminal round a suitably arranged driving gear provided with some convenient tightening device by means of which the slack and extension of the rope can be taken up as required, and at the other end or terminal is carried by a plain cast-iron grooved wheel. The tightening devices employed are usually similar to those used on underground haulage installations. Pulleys or sheaves rotatably mounted upon the posts or standards serve to support the rope between the terminals, and the carriers or vehicles are attached to it at suitable intervals by gripping devices.

It is obvious that the above grooved supporting sheaves or pulleys may consist of any ordinary and well-known types mounted in the usual manner. A number of specially constructed sheaves or pulleys have, however, been designed.

In one form the supporting sheaves for the endless travelling rope are constructed with deep flanges to prevent the rope from being jerked off, and also with raised or removable treads on which it bears. The sheaves are so dished that the bearings will be located beneath the line of the rope. At such points on the line as are exposed to great pressure, such as the ends

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of spans, it is recommended to mount two or more sheaves on simple or compound balance, or compensating levers, on springs, or on adjustable bearings, so as to distribute the strains, allow for the varying positions of the load, and to admit of the rope conforming to the contour of the ground. It is also suggested that the sheaves be mounted in canted or inclined positions at curves so as to allow of horizontal changes in direction being made without shunting on to another section.

It has been proposed to employ double pulleys or sheaves with a clearance or space between them to allow of the passage of the hangers. By this means the advantage of being enabled to hang the loads directly from the rope would be secured. In practice, however, it has been found that such an arrangement presents many difficulties against successful working, not the least of which being to ensure the passage of the hangers, which have more or less tendency to sway laterally, through the narrow clearance, the amount of which is of course governed by the diameter of the rope.

## Carrier Boxes or Saddles for Running-Rope System.

The vehicles or receptacles for the conveyance of goods or passengers, including the means employed for suspending them from the rope-way, are usually known by the name of carriers, and in the system of wire rope-ways under consideration in which an endless travelling rope is employed, the method of supporting them upon this endless travelling rope is such that the carriers are attached to and will travel with the rope, from which they are suspended by means of suitable frames or hangers, and boxes or saddles, several different methods being adopted for securing the latter to the rope, and the slipping of these gripping devices when inefficient forming one of the most fruitful sources of wear of the wire rope.

In one pattern the box is fixed to the rope, which is held therein by an abutment and strap, and to this box is journalled an upper hanger. The lower hanger carries the loads and is detachably connected to the upper one, and its lower end enters a V-shaped notch with a cross-rib in the carrier receptacle or bucket into which it is guided by a locking device consisting of a swinging arm. The strap for securing the box or saddle to the rope is tightened by a screw or by a jib and cotter, and the box can be placed at any angle to suit the disposition of the supporting pulleys or sheaves.

An arrangement of saddle designed by Roe and Bedlington, has clips which grasp the sides of the rope, and are tightened by the weight of the carrier and its contents acting through toggle levers, wedges, and universal joints or rollers, running on plane, inclined, or curved surfaces, the slight endwise motion of the saddle on gradients under the action of the load causing a further tightening of the jaws to take place. On passing a supporting sheave or pulley the clip jaws pass through the sheave groove whilst the saddle passes above it, and a taper nose attached to the saddle tends to bring the rope into the centre of the sheave groove if at all displaced. The saddle is also provided with two pulleys for supporting it on shunt rails at the stations, and the jaws of the clip are sometimes grooved to fit the cable or rope strands and lined with some suitable material. To prevent the saddle from tipping endways when ascending a steep gradient, the frame, or hanger carrying the receptacle, is pivoted to the saddle in the horizontal plane of the centre line of the rope.

Fig. 12 shows one of Carrington's boxes or saddles specially adapted for steep grades. The portion of the saddle which rides upon and grips the rope is fitted with a seating of some pliant material such as indiarubber, or of an arrangement of wooden or composition friction pieces or blocks, the latter being held by some authorities to be the best, as the india-rubber seatings are liable, in some cases where the gradients are very steep, to slip in wet weather. For

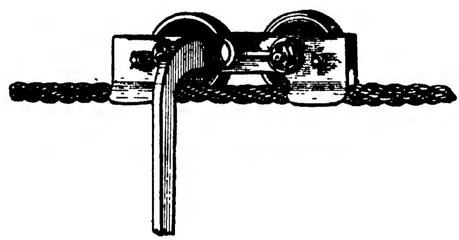


FIG. 12.—Carrier Box, or Saddle, for Steep Gradients.

additional security steel toggles are sometimes placed at the extremities, but this practice is objectionable by reason of the great wear and tear to which they subject the ropes. The external arrangement and construction of the saddle are sufficiently apparent from the illustration.

The frame carrying the friction blocks or pieces is generally made of malleable cast iron, with wings at each end, which, when the carrier is passing a rope-supporting pulley, embrace the pulley rim.

Small shunt wheels are mounted upon pins carried in the frame, as shown, and serve to remove the carrier from the rope at the terminals, and at the curves, where shunt rails are fixed for that purpose.

Another form of saddle has a V-shaped groove, also lined with indiarubber or other elastic material at each end, which grooves ride on the rope, and the indiarubber by engaging with the wires obviates any tendency to slipping under ordinary conditions. At the central portion, which is clear of the rope, a pair of jaws grips the wire-work freely on inclines. To effect this the load is suspended from a horizontal transverse shaft on the top of the saddle, and a vertical stud is provided on the former having at its top a horizontal shuttle-shaped piece placed in the direction of the rope. The arms of the grip are forked fore and aft, the prongs rising opposite the pointed end of the shuttle, which, when the saddle assumes an inclined position on a gradient, enters between the forked arms and causes the jaws to grip the rope by reason of the weight hanging in a vertical direction, and so causing the shaft to rotate relatively to the saddle.

A type of box or saddle for steep grades is so constructed that it is capable, whilst riding on the rope of passing through an enlarged groove provided on the supporting pulleys. The frictional connection to the rope is in this case usually discarded in favour of a mechanical device which grips the rope, or, in some cases, of an arrangement of clip, consisting of a lug cast on to the frame or to a movable portion of the latter, and resting between the strands of the rope.*

The Hallidie clip is one which is rather extensively used, and has been well spoken of. It consists essentially of two parts connected by a pin forming a hinge joint opening upwards. On the extreme end

* See description of running-rope system on this plan, pages 45-50.

of the body or main part is a spiral web that enters the rope. Two prongs on the other end of this body are drilled to receive the pin, and the piece jointed to the body by the latter has an arm which forms a journal, a lip or projection preventing the joint from working downwards. The spiral web on the body has five concave corrugations or scores and one convex corrugation, and is formed to suit the pitch of the strands of the rope in which it is to be entered, and also the size of the latter, so that the rope will fit accurately in the corrugations.

When in place in a six-strand rope the first corrugation will receive the heart or core, and the second and third receive the two outside strands of the rope. The third of the three bottom strands will lie beneath the core which is in the first corrugation or score. The sixth convex corrugation on the upper side of the web will take the place of the upper half of the core, and the fourth and fifth corrugations will take one strand each, whilst the third will lie on the top of the sixth corrugation. An almost perfectly round rope is thus, it will be seen, secured at the point of attachment.

On the inner end of the above-mentioned arm is cast a solid collar, and a loose collar or washer placed at the free or outer end and retained in place by a split pin, forms the journal upon which can be mounted the carrier or hanger frame.

In work, when passing a sheave or pulley the body rides on the rim of the sheave, and is raised up as it travels over it, gradually falling as it passes until the joint takes its bearing, the shaft or journal remaining during the movement in a horizontal, or approximately horizontal, position.

The advantages claimed for this clip are:—Owing to the clip being hinged and inserted into the rope without the form of the latter being altered at the point of insertion, no swelling is produced on the rope, and the clip can pass over a sheave without jar to the rope, or throwing the load out of its vertical position, thus avoiding the detrimental swinging action which takes place when rigid clips are used. This hinged arrangement, besides, admits of very deep wide grooved sheaves or pulleys being used, and the liability of the rope being jerked out of place is thus reduced to a minimum. With ordinary clips, on the contrary, the rims of the sheaves have to be cut down so that the grooves will not be deeper than half the diameter of the rope, and consequently the danger of the latter leaving them is considerable. The clip can also be very readily attached to the rope, and can be easily advanced on the latter from time to time, so as to distribute the wear, and prolong the life of the rope. It is cheap, and does not require, as is the case with some forms of clips, to be bent round the rope whilst hot, thereby affecting the temper of the latter and frequently considerably reducing its tensile strength.

## Wire Ropes or Lines for the Fixed Carrying-Rope System.

With respect to the second main class of wire ropeways mentioned, that is, those in which a strong fixed carrying rope forms each of the lines, tracks, or ways and a light running or travelling rope is employed in conjunction with it for driving or haulage purposes, the former should be of stout steel wire, and specially designed to withstand the strains to which the line or track will be subjected in working; and the latter should preferably consist of fine steel wire, and be made on the Albert lay, and with a hempen core so as to ensure the maximum degree of flexibility.

The fixed rope forming the track or line is sometimes solidly anchored at each end, suitable means for straining or taking up the slack being provided at a point, or at points, along the line. In other cases it is anchored at one end only, and strained at the other end by heavy weights passing over pulleys, a weighted anchor carriage, or by winding it on a drum, &c.

The posts or standards used in lines on this system do not differ materially from those employed for the running or endless rope system, and the wooden and iron posts or standards shown can be arranged to suit either the running-rope system or the fixed carrying-rope system.

The fixed carrying rope is as a rule supported at the posts or standards in iron saddles, seatings, shoes, or cradles so formed as to afford no obstruction to the passage of the grooved wheels of the carrier-travellers or trucks running on the rope, whilst the light travelling hauling or driving rope is held up simply by its attachment at frequent intervals to the carrier frames or hangers, except where such intervals or spaces are of considerable extent, in which case the rope is generally arranged to rest upon rollers rotatably mounted upon arms, brackets, or cross-pieces fixed to the posts or standards.

The method of supporting the carrying rope is of considerable importance, as, by reason of variations in temperature and in the positions of the loaded carriers, the ropes have a considerable endwise movement imparted to them, which, if they should become fixed in their saddles, seatings, or shoes, would tend to overturn the standards, and in any case is likely to give rise to a considerable amount of wear. To overcome this objection the ropes are sometimes carried on grooved sheaves, but the small amount of bearing surface afforded by these also entails excessive wear. More successful methods are those wherein the blocks or shoes are mounted upon small rollers and arranged to run upon suitable races, or what is still better, secured, as in the Obach and Beer systems, to the ends of pendulum rods or swinging levers, arranged to move through certain arcs, but supported against sideway movement by quadrant-shaped guides.

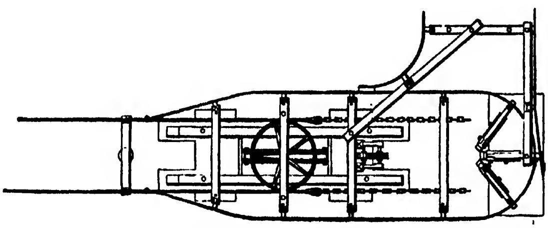


FIG. 13.—Wire Rope-Way End or Terminal. (Bleichert System.)

The terminals and occasionally intermediate points of divergence on the line, where the latter is constructed as is usual in straight sections, have to be provided with switch rails to enable the carriers to be transferred or shunted on to another line or track, or on to the second rope or cable to perform the return journey.

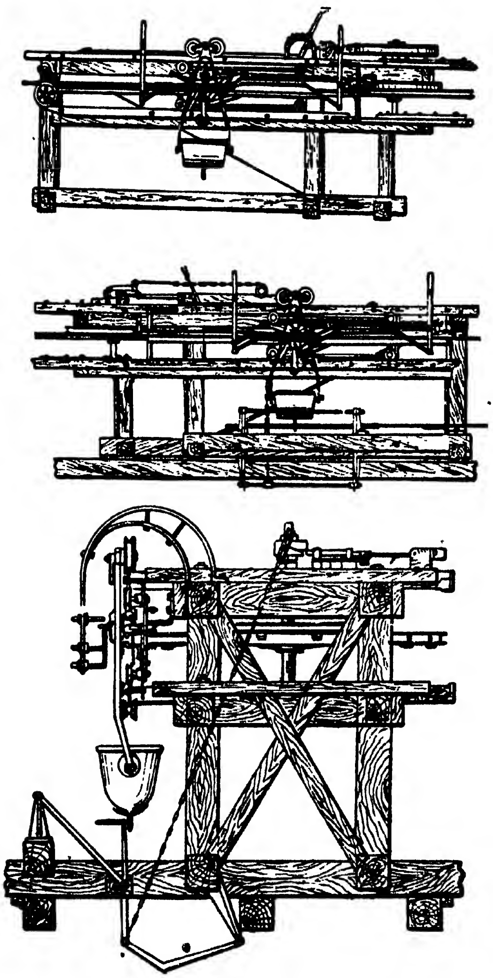
One end or terminal of a rope-way on Bleichert's system is illustrated in Fig. 13, from which it will be seen that the hauling rope passes round the horizontal pulley, and the track is connected to a rail supported by suitable brackets. The carriers may be here passed round to the second or opposite carrying-rope for the return journey, or they may be shunted on to another track by the switch rails.

When it is desired to erect portable temporary junctions at some intermediate points on the line where it is required to stop or to return the carriers to the starting point, these junctions are constructed with a connecting rail somewhat similar to that shown in Fig. 13, but arranged to dip below the ropes by means of temporary pulleys, so that they may be out of the way of carriers crossing over.

At curves the arrangement is such that the carriers leave the supporting track or carrying rope, and run, by reason of their momentum, on a connecting rail in the same manner as at the end or terminus of the rope-way, having been released from the hauling rope, by which they are again picked up on resuming their bearing on the fixed carrying rope. Both the carrying ropes, and hauling rope, pass round rollers.

Fig. 14 shows an upper terminal for a double rope line on the Leschen system with one of the carriers in position for loading. Fig. 15 illustrates a lower or delivery terminal on the same system.

The standing ropes at the upper terminal, Fig. 14, are run through castings and anchored, a track connected to the castings and bolted to the timber work taking the place of the carrying ropes. On an empty carrier arriving at the terminal it runs on to the rail round the terminal wheel to the releasing rod, where the clip is released from the empty carrier, and passes on to the loaded carrier to engage the longer of two levers called the clip lever, the carrier becoming at the same instant attached to the shorter of these levers known as the carrier lever. This latter is fulcrumed to the clip lever in such a manner that the speed of the carrier decreases gradually until it stops



FIGS. 14, 15, and 16.—Upper and Lower or Delivery Ends or Terminals, and Dumping Device. (Leschen System.)

at the loading point. The clip lever and clip meanwhile pass along until the clip comes in contact with a device for accelerating the carrier, which until then has been loading, and the latter is gradually moved from its stationary position until it receives the full speed of the hauling rope, when the clip becomes locked in the clip frame and the carrier passes along the line, and the two levers then return to their original position ready to receive the next arriving carrier.

The lower terminal shown in Fig. 15 has a similar arrangement for automatically handling the carriers to and from the running rope. This terminal is mounted on sills to admit of its sliding backwards and taking up the tension on the running rope and so controlling the latter independently of the carrying rope. In the illustration an empty carrier is shown ready to go up the line, and as a loaded carrier is released on its arrival from the hauling rope at the yoke its speed is gradually decreased through the series of levers as described with reference to the upper terminal. The clip goes on to the accelerator and picks up the empty carrier which passes round the lower terminal wheel, the levers return to place, and the loaded carrier stops at the discharging point.

The timber required for the erection of each of the above terminals is as follows:—Main sills, two pieces, 10 in. by 10 in. by 22 ft.; cross sills, three pieces, 10 in. by 10 in. by 16 ft.; top frame, two pieces, 10 in. by 10 in. by 20 ft.; centre, two pieces, 8 in. by 8 in. by 20 ft.; short posts and headers, one piece, 8 in. by 8 in. by 16 ft.; posts and back cap, three pieces, 10 in. by 10 in. by 12 ft.; headers, one piece, 10 in. by 10 in. by 10 ft.; headers, one piece, 8 in. by 10 in. by 6 ft.; track girts, ten pieces, 4 in. by 6 in. by 16 ft.; 500 ft. of 1-in. boards.

Fig. 16 shows in end view the Leschen dumping device which when in action makes one revolution of the terminal shaft and stands at rest until again thrown into action. During this revolution the dumping rods are operated and coming in contact with a pin on the bottom of the carrier tip up the latter and entirely spill the contents. No violent action takes place, the dumping rod being merely pulled up and let down. The clip passing from one carrier to the next is guided by the slot rail shown so as to ensure its being in its proper place to strike the accelerator.

In the Leschen system there are always two stationary carriers, one at the upper terminal ready to load or loaded, and one at the lower terminal dumped or ready to be dumped.

Amongst the various other plans that have been adopted or suggested for the arrangement of the ropeway the following may be mentioned :—Connecting the carrying rope by ties at fixed intervals to another rope suspended from posts or supports consisting alternately of one of considerably greater height, so as to form, as it were, a flexible girder. In the case of double lines stretchers or crossheads being provided to maintain the ropes parallel, and to enable loads to be suspended when desired from both lines. The carrier supports and carriers need not in this case differ from those ordinarily employed.

Supporting the weight of the carriers by means of several wires so arranged that the tension of the wires will be independent of the load. These wires are fixed at one end or terminus, and are passed over grooved pulleys at the other end or terminus, and connected to heavy weights. The driving, propelling, or hauling ropes are arranged side by side with the above, one end of each being attached to the carrier, passed around pulleys, and back to the other end of the carrier, and there secured. The hauling or driving rope is driven by a suitable pulley, which latter is rotated by an engine located at the rear of the casing carrying the supporting pulleys, and provided with guides for the suspension tension weights. These latter consist of two side plates carrying between them at the top a loose pulley, and having supports for removable bars forming the adjustable part of the weight.

In another arrangement of rope-way suggested by Hodgson, a rope was to be laid parallel to the bearing or carrying rope, which second rope was to be capable of taking a strain similar to that thrown by the loads upon the bearing or carrying rope, and was to be clamped by a clip formed with spiral grooves corresponding to the lay of the rope, to the supports of the main carrying rope. The main carrying rope was to be first laid with a sag so as not to overstrain it, and then the second sustaining or carrying rope strained whilst unloaded to its maximum strain.

Many plans have been proposed for enabling curves to be rounded at angles instead of shunting the carrier on to a rail, and thence to another rope-way or section, diverging in a straight line from the first. In one arrangement the bearing or carrying rope is replaced at the curves by rails, and the traction or hauling rope is guided by pulleys supported in a rail on which run wheels on the vehicle suspending or carrier frame, and rope-gripping apparatus. The track is supported by two crossed poles with inclined struts, the poles being held where they cross by a bolt and a double channel section. The traction or hauling rope may be run at the terminal station round a horizontal pulley with a flange, against which the above-mentioned wheels engage. The bearing or carrying rope and traction or hauling rope pulleys, &c., are supported on brackets on the cross-pieces, which brackets, near the terminals, are mounted on slides vertically adjustable by screws, or other means, so as to enable the required incline to be obtained.

## Carrier Trucks, or Runners, for the Fixed Carrying-Rope System.

The carrier receptacles in this system are suspended from what are called indifferently trucks, travellers, runners, or saddles, the ordinary form of which consists mainly of two grooved wheels or rollers rotatably mounted in a suitable frame. Of the several special arrangements that are also made, the best forms are those having the spindles or axles of the grooved wheels supported in bearings at both ends, instead of being arranged overhanging and supported at one end only, as is sometimes the case.

The spindles or axles in some of the best types are also formed hollow so as to provide reservoirs adapted to contain a charge of lubricant, and they are perforated with small radial holes to allow the escape of the lubricant into the journal, by which means the travellers or saddles are enabled to run for a lengthened period without attention, and the spindles and bosses of the grooved wheels caused to last for many years. The oil or other lubricant can be inserted into the hollow spindles by the removal of screw plugs.

In the ordinary form of saddle with overhanging spindle the wheels become skewed, atwist, or out of line, and consequently the carriers do not hang vertically. Considerable trouble is also generally experienced in keeping them properly lubricated.

Fig. 17 illustrates in sectional plan and elevation a truck or runner having a frame and spindles of the above-mentioned improved description. The frame is composed of two steel plates having a central cast-iron distance piece through which the hanger or frame spindle passes. The grooved wheel spindles or axles are of phosphor bronze hollowed out or recessed to contain oil or other lubricant, as shown, and also arranged to

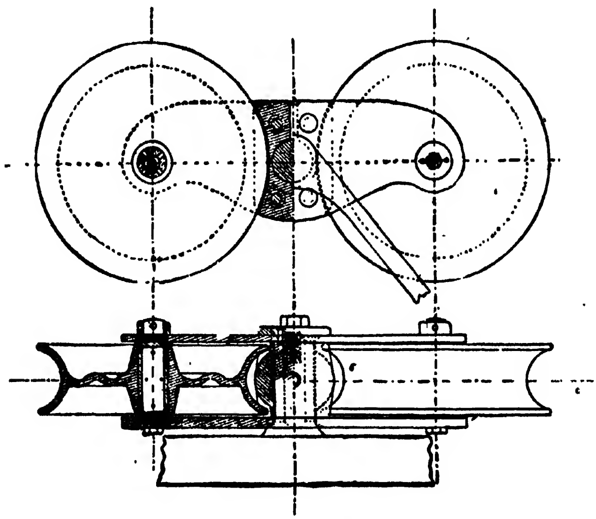


Fig. 17.—Carrier Truck or Runner. Sectional Plan and Elevation.

form end distance pieces between the side plates of the frame. The hanger spindle can be oiled through a hole in the distance piece, and the carrier frame or hanger passes through the latter, the frame being suspended from the centre, but on one side of the truck or runner, and swinging on the spindle. Fig. 18 is a perspective view showing a truck of slightly different pattern in position upon the fixed wire rope-way.

To admit of the loads being suspended directly from the carrying rope a form of truck or runner having double wheels or rollers, with a space or clearance between them, has been proposed. Through this clearance the connections by means of which the rope is suspended or supported will pass, the amount of the clearance obtainable being of course dependent upon the diameter of the rope.

Amongst the very numerous other trucks or

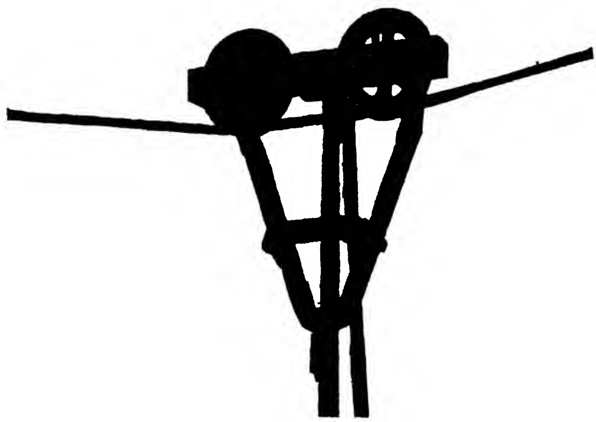


FIG. 18.—Carrier Truck or Runner. Perspective View

runners that have been designed, one has grooved wheels or pulleys mounted in a frame from which the receptacle is carried by a hanger and rods, and on the other side of which is another pivoted rod which takes on to a stud on a second rod, a third pivoted rod taking on to a stud on the first rod. The office of this latter rod is to prevent the truck or runner accidentally leaving the rope, and to admit of its passing the supports on the posts or standards, fixed inclines being there provided to knock the rods out of the way at these points. Another has provision made for preventing its being jerked from, or otherwise getting off the carrying rope, consisting of a saddle framing fitted with two or more rotatably mounted grooved wheels or pulleys intended to run upon the fixed carrying rope, and one or more similarly grooved wheels or pulleys mounted in a like manner, and adapted to engage with the under side of the rope, so as to prevent the possibility of any accident arising through the above-mentioned cause. The frame of this saddle is also formed fender-shaped at each end in order to remove any obstructions, such as branches, from the carrying rope.

In practice additional safety arrangements for preventing the trucks or runners from leaving the carrying rope are found to be unnecessary on lines working under ordinary conditions.

A number of so-called safety suspension devices or trucks have been likewise devised, the general idea in all of them being to provide some form of clutch which will act automatically to grip the rope-way should the driving or hauling rope break.

In one form, upon the accidental breakage of the hauling rope, a bridle to which the latter is attached will fall and release detents, thereby allowing of springs coming into action by which gripping rods, jointed in a manner practically similar to a parallel ruler, are caused to grip the rope-way through links and levers. A pusher piece is forced by a suitable stop to shoot beneath a snug on the bridle, and prevent its falling, and the clutch from coming into action at the termination of the travel or journey.

Another type of carriage or truck, in addition to a safety clutch device, has suitable mechanism by means of which the carrier receptacle can be lowered at one of the termini. This arrangement is intended especially for hoisting and conveying coal and other materials from mines, vessels, &c.

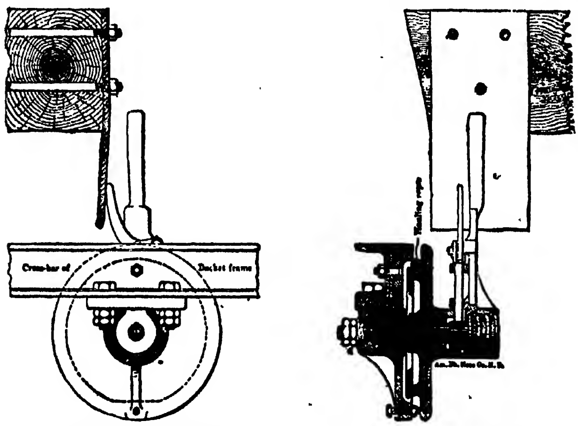
There are numerous other patterns of trucks or runners which space does not admit of even briefly describing here, but a few of which will be found noticed and illustrated in the descriptions of installations that are given in succeeding chapters as examples of lines that have been erected and are working in various parts of the world.

## Friction Grips or Couplings.

To attach the carriers to the hauling rope some kind of clip, coupling, or grip is required, and if regularity and uniformity of working is to be attained, this device must be both simple in construction, certain in its action, and calculated to produce as little wear of the rope as possible. Indeed it has been the experience of most engineers, with regard to wire ropeways, that the slipping of the clips on the carrying rope in the one system and on the hauling rope in the other, is one of the chief causes of their deterioration.

The couplings or grips in general use are either of the friction or of the locking types.

Figs. 19 and 20 show in elevation and in vertical section a form of grip or coupling of the first-mentioned class, which consists, as will be seen from the illustration, of two smooth-faced discs, one firmly attached to the crossbar of the carrier frame or hanger, and the other rotatably mounted upon a spindle, and capable of acting as a carrier or support for the driving, or hauling rope. The discs are normally retained apart by a spring, and to bring them together and grip the rope the spindle is provided with a square screw thread at its outer end, upon which the correspondingly internally screw-threaded boss of a lever is adapted to engage, so that when the latter is raised the loose disc will be moved towards the fixed one, and the rope be tightly clamped or gripped between their adjacent faces, the lever being retained in its raised position by means of a spring catch or trigger. This latter arrangement admits of the grip or coupling being automatically thrown out of action by a stop or wiper encountering



FIGS. 19 and 20.—Disc Friction Grip or Coupling. Elevation and Vertical Section.

the lever and catch, and the driving rope released, on approaching a station, when the carrier can be switched off the carrying rope on to a siding, as has been already described.

The Bleichert grip or coupling is said to be suitable for gradients up to 1 in 6, and for loads weighing up to 9 cwt. net. An advantage of no inconsiderable value, possessed by this coupling, is the ease with which it can be adapted to receive ropes of different dimensions, and to allow for the wear of the rope.

Where steeper gradients have to be surmounted, such as those up to say 1 in 3, a friction grip or coupling with corrugated jaws, one of which is rigid, and the other movable to and from the rope by means of a lever and cam, should be used, or some other more powerful form of grip than that fitted with the smooth-faced discs, as above described and illustrated.

Two forms of clips, couplings, or grips have been designed, which are constructed shortly as follows:—In the first a right and left handed screw-threaded spindle is employed. The thread engaging in the outer or first movable jaw is of a fast pitch, and, when rotated, rapidly advances the jaw against the rope and then becomes disconnected, after which the closing of the jaws is completed by the fine thread, which engages with, and acts upon the second movable jaw. A casing is provided for excluding dirt, and a lever is attached to the screw-threaded spindle which can be acted on by fixed inclines or stops at the stations so as to automatically operate the coupling or grip.

The second arrangement consists of a toggle mechanism for operating the jaws, and the grip is held closed by a pawl engaging a sector fixed on one of the jaws, and is kept normally open by a spring between the jaws.

Both of the above clips are provided with guide-rollers intended to bear upon the hauling or driving rope, and have their jaws fitted with liners to facilitate repair when worn.

In a form of coupling or grip designed by the same inventor, whose disc grip has been already briefly described and illustrated, an eccentric quadrant is caused to bear against the rope by a cam operated by an arm controlled by suitable projections provided on the line.

Another grip or clip invented by Roe and Bedlington has the jaws so mounted that they will be closed by a movement perpendicular to the direction of the cable or rope, and will be then automatically tightened by the pull of the latter. The above purpose is effected by various arrangements, such as ball-jointed jaws with eccentric faces, straight-faced jaws working on eccentric bearings, one jaw jointed to a plain or segmental toggle lever, and the other supported by eccentric rollers, and by other dispositions of toggle levers. Apparatus is also provided for entering the cable or rope between the jaws, applying the initial pressure, and locking the jaws.

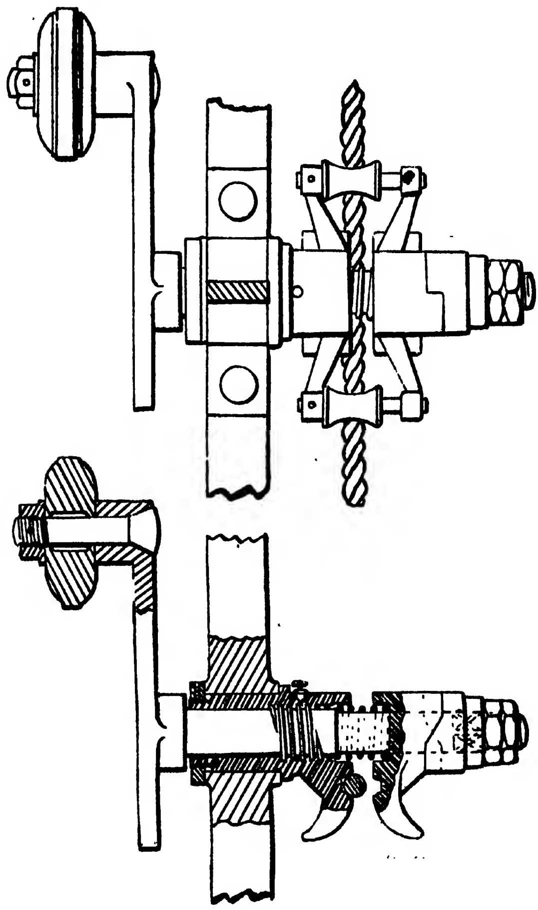
It has been also proposed to use a rope clip or grip in which the hanger is given a vertical movement in the supporting trolley or saddle, which latter is arranged to carry an upper gripping block, and to actuate a lower gripping block pivoted on the trolley through a link. A pulley running on a fixed rail raises the hanger above the ordinary carrying rope at the termini, so as to free the grip from the driving or hauling rope.

Whatever the type of friction grip or coupling, however, that may be employed, provided it be efficient in action, certain specific advantages will be derived from its use. Amongst these the most important are that, owing to the carriers being attachable to the rope at any point, the wear of the rope is rendered more uniform throughout its entire length; and, furthermore, as the carriers can be, as above mentioned, attached to the hauling or driving rope at any point, the carrying capacity of the line may be easily increased or decreased at pleasure, by simply placing the carriers closer together, or farther apart, in accordance with whether the former or latter alteration be desired.

This is, indeed, a far more desirable way of effecting the above object than that of varying the travelling speed of the hauling rope from that found to be the most advantageous rate at which to work any particular installation of wire rope-way, and more particularly is this the case when the alteration entails an increase of velocity.

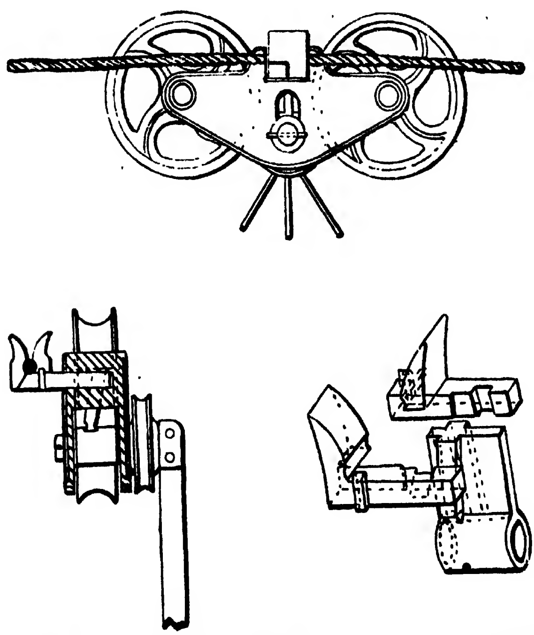
As an example of the small amount of wear caused to the rope by the use of disc friction grips or couplings, it may be here mentioned that on the Fernie wire rope-way at Giesen, where such grips or couplings were in use, the hauling or driving rope supplied when the line was erected in 1879 was stated to have still been in good condition and in regular work in 1891.

Figs. 21 and 22 illustrate in plan and section a friction coupling used by Ceretti and Tanfani on their rope-ways. The hauling rope is gripped by two jaws opened and closed by a screw and a toothed collar. A counterweighted lever, turning through the third of a circle, operates the device. One of the jaws is immovable, whilst the other has two successive movements in the same direction, the first, a quick motion, being caused by the inclined surface on a collar operating against another on the movable jaw, and the second, a slow movement which effects the gradual gripping of the hauling rope, being effected by the screw thread. The turning of the counterweighted lever in the opposite direction assisted by the spiral spring shown in the illustrations causes the opening of the grip. To render the coupling and uncoupling of the grip automatic, angle irons forming inclined planes are provided at the terminals to act on the counterweighted lever. This coupling is adapted for gradients up to 1 in 3.



FIGS. 21 and 22.—Friction Grip or Coupling. (Ceretti and Tanfani's System.) Plan and Sectional Views.

Figs. 23, 24, and 25 show side elevation, cross section, and detail views of another coupling acting on the same principle, which has been successfully employed by the above firm. In this case the grip is produced by the weight of the carrier itself acting on the jaws through a wedge having inclined surfaces, and arranged to slide within the frame. A roller mounting special rails at the termini, causes the

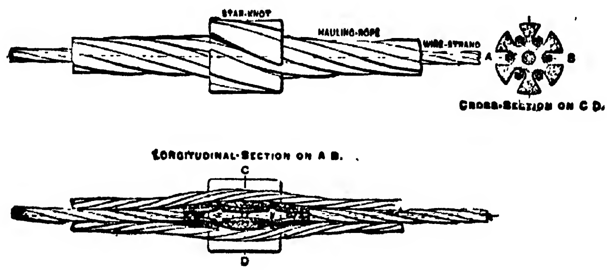


FIGS. 23, 24, and 25.—Friction Grip or Coupling. (Ceretti and Tanfani's System.) Side Elevation, Cross Section, and Detail Views.

wedge piece to rise and release the jaws. Amongst the advantages claimed for this device are the following:— It is simple and inexpensive. The coupling and uncoupling are automatic, and there is a minimum of shock. The amount of grip can be easily changed by varying the angle of the inclines on the wedge piece. When the coupling is closed the gripping strain remains constant for the whole of the run, no matter what the gradient. The device can be used to grip ropes of different dimensions without any special adjustment, thus admitting of hauling ropes of varying sizes being used on the same installation.

## Knots or Carrier Collars for Locking Grips or Couplings.

When a line of wire rope-way has gradients steeper than 1 in 3, a lock grip or coupling of some efficient

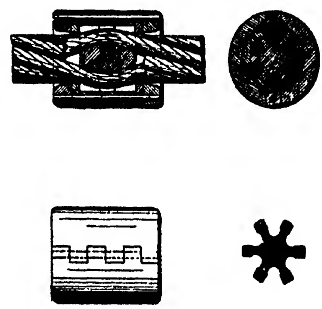



FIGS. 26, 27, and 28.—Star Knot or Carrier Collar for Use with Locking Grips or Couplings. Elevation, Longitudinal and Cross Sections.

description must be employed. There are many patterns of this type of grip and of the necessary knots, carrier collars, or swellings in the rope by means of which the fastening is completed.

With respect to the latter, that known as the Star knot is perhaps about the best. This device, which is illustrated in Figs. 26, 27, and 28 in elevation and in longitudinal and cross sections, consists of a spirally grooved cylinder having a diameter slightly larger than that of the driving or hauling rope to which it is to be fixed. Into these spiral grooves the strands of the rope, which must be untwisted for the purpose, are inserted in the manner shown in the illustrations, so that the ribs of the cylinder will project to a sufficient extent to afford a hold for the grip pawls, or for the claws of the coupling.

To ensure additional security, a couple of yards of the hemp core of the rope are besides removed, and a steel wire strand is passed through the cylinder, and fixed by wedges $x$, $y$, as shown in the longitudinal section, the steel wire strand being then put in place of the hemp core that has been removed, and the rope twisted up again, when the knot and strand will be found capable of resisting all the strains to which they are likely to be subjected whilst in work.



FIGS. 29, 30, 31, and 32.—Otto Knot or Carrier Collar for Use with Locking Grips or Couplings. Plan, Longitudinal and Cross Sections.

A pattern of knot or carrier collar, which is also capable of withstanding heavy strains, is illustrated in plan and in longitudinal and cross sections in Figs. 29, 30, 31, and 32. It consists essentially of two pieces which are held together by joints, and bolts or pins, or by means of ordinary hinge joints, and is of a cylindrical form when closed. This construction enables the carrier collar to be attached at any part of the endless rope after a suitable filling piece has been inserted between the strands of the rope to form a swelling. This filling piece is made with radial projections, and with spiral grooves, corresponding to the strands of wire forming the rope, and is turned on the outside to exactly fit the recess in the outer cylindrical casing of the carrier collar.

The attachment of the carrier collar to the hauling rope is made by untwisting a sufficient length of the rope and removing the hempen core or interior for a length equal to the length of the filling piece, which latter is then inserted. The two halves of the carrier collar are then placed over the whole and secured together by means of the joints and the bolts or pins. The radial projections of the filling piece bear against the inner surface of the carrier collar and thus prevent it from being displaced. To ensure greater security and to prevent any movement of the filling piece in the rope, white metal or other suitable alloy or composition may be run into the clearance spaces. Elastic rings formed in halves may be placed at the ends of the filling piece to cushion the force of any violent impact, and ensure its being gently transmitted to the rope, thereby preventing serious injury being caused to the latter by the gripper striking against any one of the carrier collars.

FIGS. 33 and 34.—Modified Form of Otto Knot or Carrier Collar. Longitudinal and Cross Sections.

Figs. 33 and 34 show in longitudinal and cross section a slightly different arrangement of the above-described carrier collar. In this case the carrier collar is divided transversely to form two parts, provided respectively with male and female screw threads, and holes for the reception of a bar or lever by means of which they can be rotated to admit of their being screwed together and thus firmly united. A filling-piece spirally grooved to take the strands is also fitted inside the rope to form an even enlargement or swelling which will be firmly gripped between the two parts of the collar, when the latter are screwed together. In this manner the carrier collar can be secured to the rope without the aid of any alloy, composition, or cement. When, however, a very considerable amount of strain has to be sustained by the collars owing to the work demanded of them being of an exceptionally heavy nature, or from other causes, such alloy, composition, or cement may be employed as an additional safeguard as in the case of the previously described carrier collar.

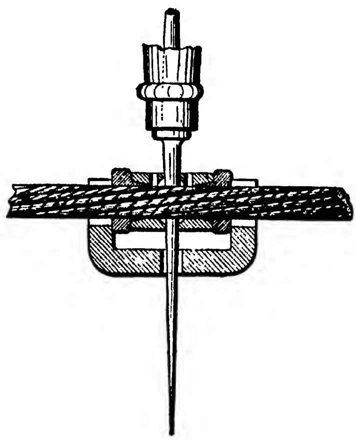
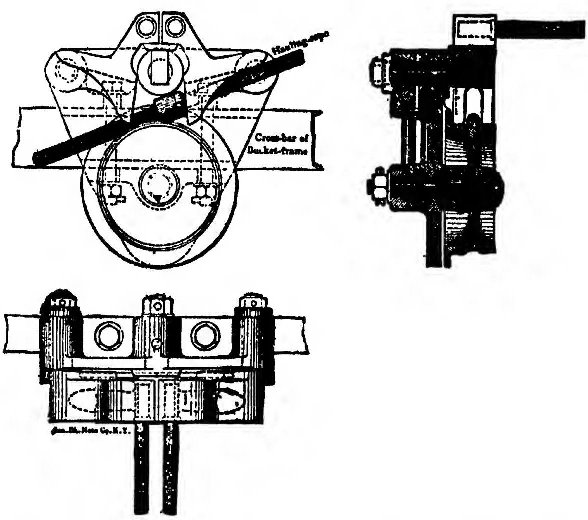


Fig. 35.—Bleichert Knot or Carrier Collar for Use with Locking Grips or Couplings.

Bleichert forms the requisite knots or swellings upon the driving rope by the use of a drum or thimble such as that shown in Fig. 35, which is attached to the rope by a lining of tin composition in the following manner:—A portion of the rope is untwisted to a certain extent, and after cutting away a certain amount of the hemp centre or core this portion of the rope is well tinned. The drum or thimble is then placed in position upon the tinned part of the rope, as shown in the drawing, and a taper pin is driven through holes in the drum or thimble, and through the rope, when, the ends having been closed by means of the split packing rings shown, and the taper pin having been withdrawn, melted tin composition or alloy is poured through the holes, and the space left by the withdrawal of the pin, &c., is filled up.

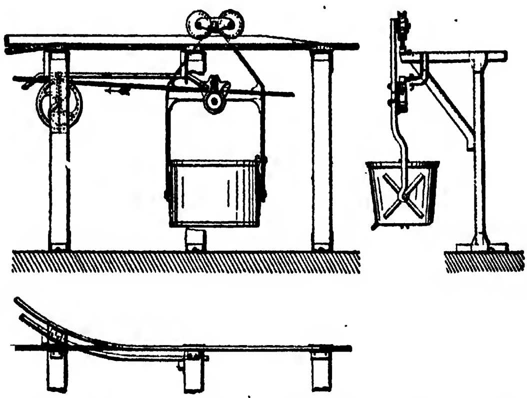
## Pawl Locking Grips or Couplings.

An excellent and simple form of pawl grip or coupling is shown in side elevation, plan, and vertical




FIGS. 36, 37, and 38.—Pawl Locking Grip or Coupling. Elevation, Plan, and Vertical Section.

section in Figs. 36, 37, and 38. It will be seen from the drawing that this grip consists essentially of two corresponding and similarly mounted pawls, each movable in a vertical plane, and having a forked end adapted to engage on each side of the knot, the amount of fall or drop, of which the pawls are capable, being limited by a stop, and the hauling or driving rope resting on a grooved roller located immediately below, and centrally between the pawls. Pins or projections upon arms on these pawls (see the plan view and vertical section) engage with a guide rail fixed at each of the stations, and serve to throw the pawls out of gear, and disengage the hauling rope. The apparatus is attached to a crosspiece of the suspension frame, as shown in the illustrations, and is equally suitable for right or left-handed wire rope-ways.



FIGS. 39, 40, and 41.—Arrangement for Automatically Connecting and Disconnecting Pawl Grip. Plan, Side, and End Elevation.

This pawl grip admits not only the connecting of, but also the disconnecting of, the hauling rope to be performed automatically. The arrangement for this purpose is shown in plan, side, and end elevation in Figs. 39, 40, and 41, from which it will be seen that releasing rails are employed, which rails are fixed at the different stations. These rails raise both pawls (which fit over the rope like a fork) by coming into contact with pins, or projections on them, and they are arranged in a similar manner for the arriving as for the departing carriers. The rails are located on one side of the apparatus and commence about a yard before the point at which the switch rail is inclined or tapered toward the carrying rope, and they are placed parallel to the switch rail. The height of the releasing rail corresponds with the position of the pawls when out of gear with the hauling rope, and they are preferably bent downwards at either end to ensure their getting under the above-mentioned pins, and gradually lifting the pawls as one of the carriers approaches. This releasing or disengaging action takes place only when the approaching carrier has arrived on the switch rail, by which means the pushing of the carrier on to the latter by hand is dispensed with. It is, however, necessary to push the departing carriers off the switch rail on to the carrying rope, but before the carrier approaches the hauling rope, the pawl will already have been lifted by the releasing rail, and this rope, which is in motion, can rest on the roller which is free to revolve, and on pushing the carrier runner or trolley further on the carrying rope, the pawls will drop. To more certainly ensure the engagement of the pawls with the hauling rope, springs may in some cases be employed.

In operation the carrier having been moved along the switch rail to the carrying rope, and the pawls having been thrown out of gear, as above described, so as to allow of the hauling rope being guided and placed upon the grooved roller rotatably mounted on the grip, the pins or projections are released from the guide rails, and the pawls fall into their operative positions. An approaching collar, knot, or enlargement on the hauling rope moves along the inclined surfaces on the pawls, and after raising and passing the first pawl moves into the space between the bolt and roller, and is gripped by the second one, any further forward movement thereof being thereby prevented. The first pawl then falls behind the collar, and the carrier is moved forward and is hauled to the following station, or the next releasing rail.

An alarm or signal bell is usually arranged to sound on the approach of one of the knots, so that the operator may push off and give a certain amount of impetus to the carrier, and thus prevent an excessive shock from occurring between the approaching knot and the grip. The uncoupling is effected by the pins or projections engaging, as before mentioned, with a guide rail, and raising the locking pawls out of gear, thus allowing the knot to escape, and releasing the carrier, which moves off the carrying rope by reason of its momentum, a tongued rail being usually provided for switching it into a siding.

Loads of more than a ton can, it is said, be carried with safety upon mountain lines up gradients as steep as 1 in 1 by means of these automatic pawl locking couplings or grips.

An arrangement has also been used wherein the hauling rope is held by the pressure resulting from wedge pieces acting on inclined surfaces, which is claimed to have given better results in the working of the rope.

## Claw Locking Grips or Couplings.

A claw locking grip designed by Bleichert is shown in Fig. 42. The driving rope is supported upon a grooved wheel or roller, and two forked bolts embrace the knot or carrying collar on the driving or hauling rope, one from each side, that on the side from which the rope moves or travels being normally held in position by a spring, but having an inclined face presented to an approaching knot, so that it will be lifted by the latter, and will then instantly drop, and thus confine the knot or collar between it and the second fork, which latter is fixed. These forked bolts are attached to a casting or block which slides vertically in guides in the framing, and is held in position by a suitable spring bolt. A projecting inclined face, placed before the intended stopping point of the carrier, engages with the point of a hook piece, slightly lifting it, and thereby depressing the spring bolt through the medium of an arm and another bolt (as shown in the drawing); on further lifting the hook the block carrying the forked bolts will be raised, and with it the two forks, so as to release the knot or carrier. The spring bolt, which during this time is between two projections, may be disengaged by a piston, or plunger, and the whole of the sliding block or part be withdrawn vertically or again lowered.

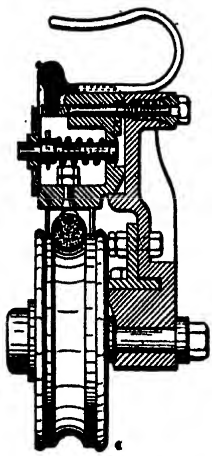
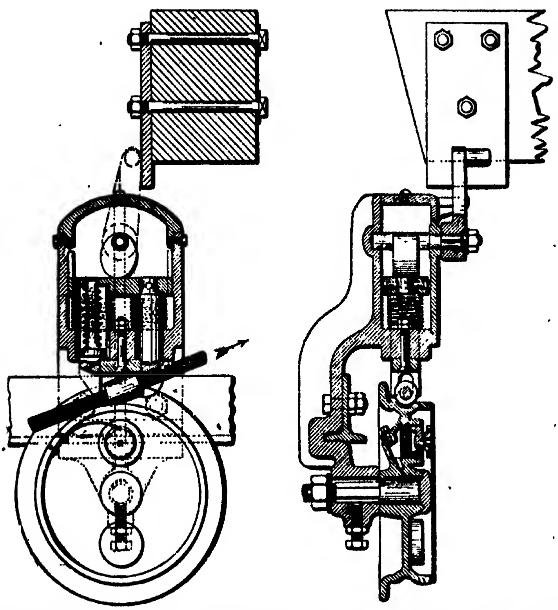


FIG. 42.—Claw Locking Grip or Coupling.

Figs. 43 and 44 show two sectional views of a claw grip or coupling which is also said to be very advantageous for use on steep gradients. To the crossbar of each of the suspension frames or hangers of the carriers, a suitable casting or frame is firmly attached, in which a roller rotatably mounted upon a spindle is designed to act as a guide and support for the driving rope, when the bucket or other receptacle is uncoupled. In this roller is a recess or chamber for oil or other lubricant, which latter is retained in the same by a screw plug, and passes on to the spindle as required through a hole or oil-way; another screw plug, by removing which the oil-way can be cleaned out when necessary, is also provided. A spring which engages with ratchet teeth upon the head of the first-



FIGS. 43 and 44.—Claw Locking Grip or Coupling for Steep Gradients. Longitudinal and Cross Section.

mentioned screw plug prevents it from shaking loose and leaving the recess. Above the roller is a cross-head supported upon springs, so that it may be moved vertically in guides formed on the frame, and having attached to its lower side a forked gripper and a sleeve, which latter carries another gripper which is constantly pressed by means of a spring against an inwardly projecting rim or flange at the lower end of the sleeve. An eccentric either attached to or forming part of a spindle carried in suitable bearings in the casting or frame above the crosshead, and having a projecting extremity upon which is fixed an arm or lever, is also provided, and a stop upon a cover, secured to the casting or frame, which stop serves to limit the movement of the arm or lever.

To couple or connect a truck to the hauling rope (which is kept constantly in motion), the rope must be first placed on the roller, and the crosshead lowered by turning the eccentric by means of its lever, so that the grippers will be caused to engage with the rope, the springs being at the same time compressed. Carrier collars or knots are fixed at suitable intervals upon the hauling rope, and on one of these carrier collars approaching the gripping apparatus it presses against the inclined surface on the gripper carried by the sleeve, thus lifting and passing the latter, and striking against the other or second gripper. As soon as the carrier collar has passed the first gripper, the latter will be forced down by its spring, and the coupling operation completed, the whole apparatus, together with the suspension frame and carrier attached to it, travelling forward with the hauling rope.

To stop the carrier at any desired point or part of the line the grippers must be released, and this is automatically effected, on arriving at the point at which the stoppage is to take place, by means of a fixed plate against which the eccentric lever strikes, and by which it is forced back so as to turn the eccentric and permit the springs to act and raise the crosshead, and with it the grippers, sufficiently high to allow the driving rope and the carrier collar or knot to pass freely between the grippers and the roller.

## Carrier Receptacles or Vehicles.

The carrier receptacles, whether for goods or passengers, which are suspended from the trucks or runners by means of frames or hangers, are of various patterns.

## Goods Carriers.

Those intended for materials and goods are of course made in a large number of different forms and

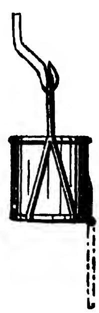


FIG. 45.—Fixed Cylindrical Receptacle or Bucket with Hinged Opening Bottom.

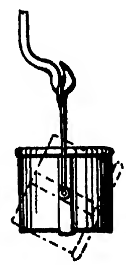


FIG. 46.—Tilting or Tipping Cylindrical Receptacle or Bucket.

sizes, being usually, indeed, specially designed to meet the requirements of the material or goods to be transported, and of the particular installation. Under these circumstances it would be obviously impossible to do more than briefly describe a small selection of carrier receptacles of the descriptions most generally employed.

To commence with carrier receptacles for minerals, which are the materials, perhaps, the most largely transported on wire rope-ways, Figs. 45, 46, and 47 illustrate three forms of receptacles, skips, or buckets employed for this purpose. Those shown in Figs. 45

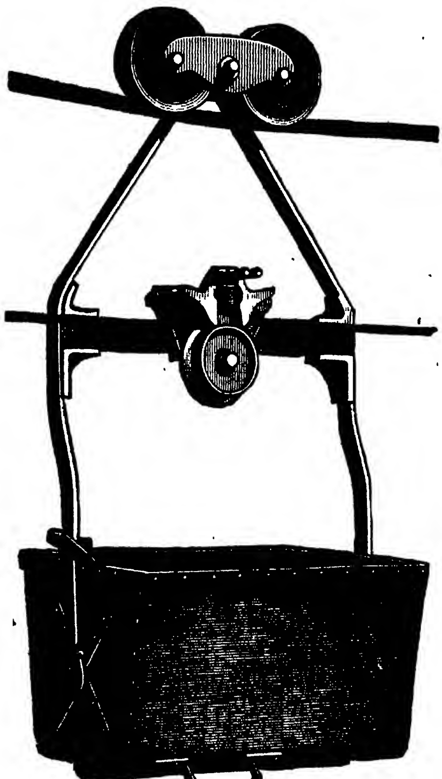


FIG. 47.—Sheet-iron Tilting or Tipping Rectangular Receptacle or Bucket.

and 46 are respectively a fixed cylindrical bucket with hinged opening bottom, and a tilting or tipping cylindrical bucket, both of which types are, with certain modifications of shape and size, very frequently employed. Fig. 47 illustrates a sheet-iron tilting or tipping rectangular bucket, fitted with special tipping arrangements as shown in the drawing.

Fig. 48 shows a produce carrier receptacle, which consists simply of an ordinary basket, the shape and dimensions of which may of course be varied to a considerable extent according to circumstances. This receptacle is suitable for the transportation of farm and garden produce, manure, coke, &c.

Figs. 49 and 50 illustrate two arrangements for carrying sacks of flour, coal, &c. That shown in Fig. 49, which is made in the form of a cradle, and is

Fig. 48.
Produce Carrier Receptacle.

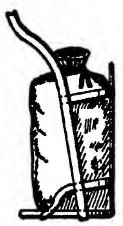


Fig. 49.
Cradle Sack Carrier.

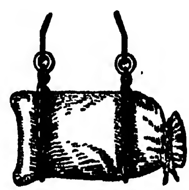


Fig. 50.
Sling Sack Carrier.

adapted to support the sack in a vertical position, is a pattern employed to a large extent at coaling stations for the purpose of supplying passing steamers with fuel, in which cases it is usual to sell the coal by the sack as a ready method of estimating the quantity supplied. The carrier arrangement shown in Fig. 50 is one of the ordinary sling type.

Fig. 51 shows a carrier receptacle intended for the conveyance of textile goods, and is a sample of a type much used on aerial or wire rope-way installations erected at textile factories in the Manchester district and elsewhere. The closed box-shaped receptacle illustrated admits of this class of goods being carried from place to place without any danger of their being injured by exposure to the weather.

Fig. 52 and Figs. 53 and 54 show two arrange-

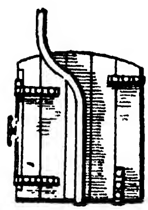


FIG. 51.
Textile Goods Carrier Receptacle.

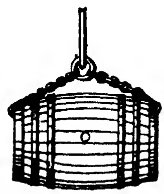
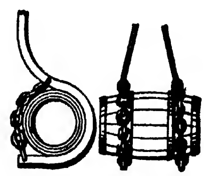


FIG. 52.
Sling Cask Carrier.



FIGS. 53 and 54.
Gunpowder Cask Carrier.

ments commonly used for carrying casks. That shown in Fig. 52 is the form of sling usually employed for casks containing cement, petroleum, wine, beer, &c. That shown in side and end elevation in Figs. 53 and

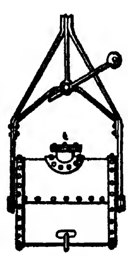


FIG. 55.—Liquid Carrier.

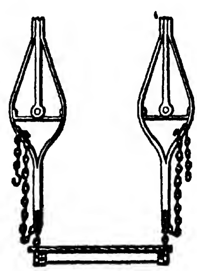


FIG. 56.—Timber or Bale Carrier.

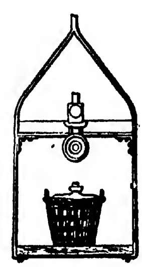


FIG. 57.—Platform Carrier.

54 is the type of carrier employed at the gunpowder magazines belonging to the British Government, where they are used for transporting gunpowder casks on a wire rope-way from the magazine to the examin-

ing house, which is usually situated at a distance of about a quarter of a mile from the former. These

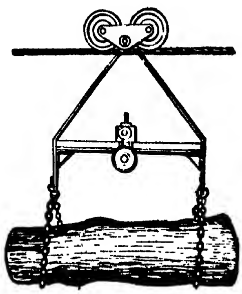


Fig 58.—Sling Wood Carrier.

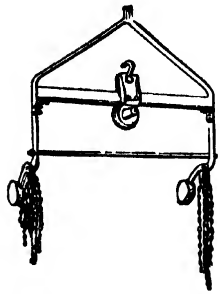
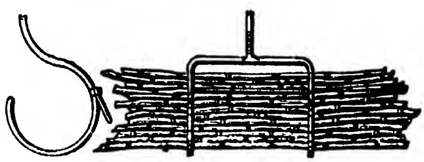


Fig. 59.—Carrier for Transporting Cannon.

cask carriers are either made of gun-metal or of galvanised iron.



Figs. 60 and 61. Sugar Cane Carrier.

Fig. 55 is a liquid carrier. Fig. 56 is a carrier for either timber or bales. Fig. 57 is a platform carrier. Fig. 58 is a sling wood carrier. Fig. 59 is a carrier intended for transporting cannon. Figs. 60 and 61 show in side and front elevation a device for carrying sugar cane. The cane stalks are placed, as depicted in the front elevation, in a double hook, forming a species of cradle, the capacity of which will of course vary according to circumstances,

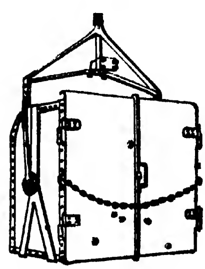


Fig. 62.—Sugar-Bag Carrier.

the loads ranging from 1 to 4 cwt. The cradles are usually so constructed as to discharge their load upon the striking of a catch.

Sometimes the space between the arms of the hooks is filled up with wire netting so as to prevent any short lengths of cane from falling through. Fig. 62 is a sugar-bag carrier of the type commonly used in usines and sugar refineries.

FIG. 63.—Passenger Carrier for Running-Rope System.

## Passenger Carriers.

The following are two carriers for passengers, constructed by Bullivant & Co. Ltd., which form typical examples of those commonly employed on wire ropeways. Fig. 63 is a light passenger carrier for the running-rope system, capable of transporting two persons seated face to face as shown in the illustration.

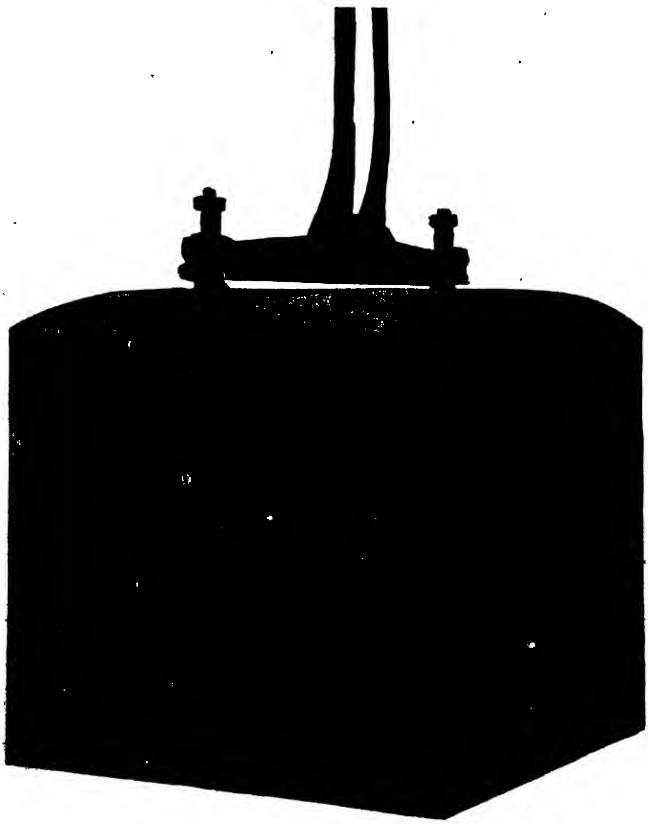


FIG. 64.—Passenger Carrier for Fixed-Rope System.

Fig. 64 is a carrier for passengers, capable of accommodating ten persons, intended for use on the fixed-rope system.

## Motive Power.

The motive power for use in connection with wire rope-ways may be derived in some cases, where the working conditions permit of this arrangement being used, from the force of gravity developed by the descending loaded carriers. In other instances water, steam, animal, or other power may be employed, and, in the case of lines on the fixed carrying-rope system more especially, electricity may in some cases be advantageously utilised as a motive power, what is known as telpherage being the most preferable arrangement to adopt.

The most suitable type of motive power and the best method of applying the power to drive the line are naturally to a great extent governed by the special features of each particular installation. Some plans of driving that have been used will be found briefly described in the accounts given in subsequent chapters of the various typical installations that have been erected at different parts of the world, and a description of the telpher system will be found in the next chapter.

One arrangement for driving endless wire ropes that was patented a considerable number of years ago, consists in an arrangement of two pulleys loosely mounted on the driving shaft and driven by bevel or mitre gearing. Two independent pulleys are also mounted on another shaft, and a pulley on a tension carriage. The wire rope is wound round the driving pulleys and the independent guide pulleys alternately, after which it passes round the pulley on the tension carriage and to line.

In a special form of grooved driving drum, around which the rope or cable is wound, the grooves are formed in independently rotatable rings, which latter are preferably made of wrought iron or steel. The first ring is fixed to the flange of the drum by bolts, and the others are kept in place by a movable flange or plate bolted to the rim of the drum. In another modified arrangement of the above, one or more grooves are fixed, whilst the other grooves, and all the grooves on the loose pulley, are carried in rings capable of rotating on the drum independently of the shaft.

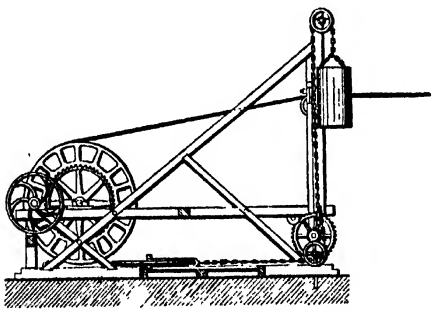


FIG. 65.—Arrangement for Driving Wire-Rope Tramway, Bleichert System.

Fig. 65 illustrates a method of driving devised by Bleichert. Loosely mounted upon the same shaft as the driving wheel or pulley is a second or other wheel or pulley of the same diameter, round which, and a horizontally mounted wheel or pulley, the endless driving, running, or hauling rope is passed. This horizontal wheel or pulley is so mounted, as will be seen from the illustration, as to be capable of sliding between guides, and a weight attached through a chain to this wheel maintains the rope taut. A windlass is also connected to the chain as shown, which admits of the cable or rope being slackened, and likewise prevents the fall of the above-mentioned weight in the event of the rope breaking.

The cheapest method of working an aerial or wire rope-way is of course the force of gravity, which plan can be adopted on the endless-rope system or on the double fixed carrying-rope system where the gradients admit of the loaded carriers being run down from the upper to the lower terminal of the line, whilst at the same time the empty carriers, or the latter loaded to a lesser degree with such materials or stores as may be required at the upper terminal, are hauled up. Such lines can be worked automatically where the gradients do not exceed 1 in 10. Power has occasionally to be applied to a line of this description where the inclines are very steep in order to regulate the speed with which the loaded carriers travel down the line by gravity. In ordinary cases, however, in which the inclines are severe enough to call for control, but are not excessive, the speed of the descending carriers can be sufficiently governed by means of automatic brakes.

Attempts have been made to design lines upon which the loaded or empty carriers can be run in both directions by the force of gravity. The limited capabilities and consequent few possible advantageous applications of any such arrangement are, however, very obvious.

The following is a brief description of a line of this kind. At each end or terminal a strong standard or support is erected, to which is centrally pivoted a lever provided with wheels or pulleys around which a continuous or endless wire rope is passed. This rope is permanently attached at one place to one of the levers. The lower stretch of rope is provided with tightening. The carrier is suspended from a pulley or grooved wheel running upon the upper stretch of rope. This arrangement enables one of the levers to be raised into a vertical position whilst the other is in a horizontal position, so that the wire rope-way will become inclined to the latter end, and the carrier run to it from the former end by gravity. The position of the levers may then be reversed by means of suitable gearing operated by hand or power, and the wire rope-way becoming oppositely inclined, the carrier will again return under the action of gravity to the starting point, and so on *ad infinitum*. For carrying goods, auxiliary line attachments passing over rollers at the stations may be provided, and a vehicle for workmen, it is claimed, might also be hauled by another driving rope over the lower stretch of rope-way.

Another arrangement for attaining the end in question, and that most commonly employed, is to secure the rope or cable at one or both extremities to a running block, frame, crosshead, traveller, or carriage, capable of being moved vertically on the post or support, by means of a hand-power windlass or crab, steam winch, steam or hydraulic cylinder, &c.

The necessary difference in the elevation of the rope or cable forming the line or track is also frequently effected by means of ordinary derricks.

Next in point of economy to gravity comes water power; it is comparatively seldom, however, that the location of the line is such as to admit of its use. Wherever this is possible, it can be invariably employed with great success.

A somewhat curious form of motive power, which it has been proposed to utilise, is the ascensive power of a balloon. A truck or runner with grooved wheels to engage with both the top and bottom of the carrying rope is to be used, and to a link on the upper side of this truck the balloon is to be secured whilst the carrier is to be suspended from its under side. On rising ground the carrier would, it is averred by the projector, be hauled up the incline by the balloon, which would have a tendency to ascend. On level ground he states that by leaving the rope slack, so that the balloon might rise, it would in so doing haul the carrier along the rope, after which it would have to be drawn down, and a fresh start made.

The balloon would evidently have to be transferred to another carrier, as also the load, at the termination of each section of rope, and the use of the balloon in high or contrary winds would be a matter of great difficulty, if not totally impossible, an obstacle which would be sufficient in itself, without mention of the numerous other objections, to render the plan impracticable.

The use of electricity for driving affords in many cases some further advantages of importance over other applications of motive power.

An obvious advantage possessed by electrically driven installations generally, especially in the case of those of any considerable length, is the dispensation of the running or travelling hauling rope, only the fixed carrying rope or ropes being required.

Unfortunately, however, wire rope-ways are as a rule unavoidably subjected to a good deal of hard usage, a course of treatment which the delicate and complicated arrangements of electrical devices are but ill adapted to withstand, and consequently when in the hands of rough and unskilled attendants, the installations, although more or less perfect theoretically, are liable to go wrong, and to give trouble. Electrically driven wire rope-ways are therefore only advantageously applicable in certain special cases in which the site is comparatively level or at any rate no very steep gradients have to be negotiated, and where due care in working can be exercised, skilled labour being readily available for keeping the installations in proper working order. The subject of electrically driven wire rope-ways is, however, one which requires a separate chapter.

# CHAPTER III

ELECTRICALLY DRIVEN WIRE ROPE-WAYS: TELPHERAGE—ORIGIN AND ADVANTAGES OF TELPHERAGE—ORIGINAL SYSTEM OF TELPHERAGE—IMPROVED SYSTEM OF TELPHERAGE.

## Telpherage.

TELPHERAGE, which is the method of applying electricity, to which it is purposed solely to confine this chapter, has many specific advantages over other electrical systems which will be detailed later on, not the least of which being that a very effective and perfectly automatic block system is provided, the passing carrier forming its own electrical connections, and no carrier being able to get within a certain predetermined distance of that in front of it.

## Origin and Advantages of Telpherage.

To Professor Fleeming Jenkin, who died in 1885, is due the credit of both inventing and bringing to a considerable degree of perfection an ingenious system, applicable for electrically driving the carriers or vehicles on aerial ways, to which he gave the name of telpherage, a term which is derived from two Greek words meaning far carrying. A telpher is an electric truck or car employed for the automatic transmission of the carriers or vehicles by electricity to a distance independently of any control exercised from the carriers or vehicles themselves. Professors John Perry and W. E. Ayrton have also devoted considerable time to the development of telpherage, and the former has clearly demonstrated the great possibilities of the system in its own particular field.

Telpher trucks can be run either on aerial wire rope-ways or on rigid rails, the latter being either arranged as elevated lines or on the ground, the aerial system being the only application that will be dealt with in this book.

The special advantages inherent to the telpher system of driving are as follows:—The conductor being insulated and only connected with the rubbed wire rope-way when a train or carriage is in the vicinity, the section of the line behind the train will consequently be incapable of leakage, owing to its not being connected with the dynamo machine, and only the particular section which the train happens to be connected with will be capable of leakage. Another important advantage due to this system of insulation is that, as has been already mentioned, it ensures an absolute block system, for say, if, by way of example, a line were supposed to be divided into three sections, and a train or carriage be on the second one, no electricity would be given to the first section at all, the current being cut off by the first train on the second section, and a second train on the first section being by a simple electrical device prevented from getting any electricity until the first train should have left the second section, and in like manner the second train being prevented from getting any electricity on the second section until the first train should have left the third section, and so on, a section being thus always interposed between each of the trains, and the following train being prevented from approaching within a specific distance of the first or leading train.

This action takes place automatically, and no driver is required to the separate trains, which are forced to retain a certain order, and the stoppage of one train will automatically arrest all the following trains at a certain distance from each other, by both removing the source of motive power therefrom, and also by applying very powerful brakes.

Curves can be negotiated as easily as on a surface line, thus admitting of the direction of the line being altered as often as desired in order to avoid excessive gradients, or for other reasons. This latter is a distinct advantage possessed by telpherage over other systems of aerial lines in which an alteration in direction necessitates the provision of an angle station.

## Original System of Telpherage.

Many hundreds of patents in this country and abroad have been taken out for improvements in telpherage. Briefly, the system as first successfully introduced was as follows:—Wheels were arranged to run along a strained wire rope or cable through which passed a current of electricity, and which formed the way or road of transport, the loads or carriers being hung below suspended from the axles of the wheels, and the rope or cable being supported at suitable intervals on posts or standards. A uniform current of electricity was supplied to the rope or cable from a station, so that the electro-motors upon the trains should be electrically connected in series through the conductor. In one arrangement a break in the electrical continuity of the rope or cable was made at each post or standard, and the sections were insulated from each other and from the earth, but the sections were electrically coupled together by movable coupling pieces. Including the electro-motor and attached vehicles, the length of a train extended to about that of a section of the wire rope-way. By arranging a coupling piece to be thrown out of action by a passing train, the electric current could be caused to flow, by a conductor on the train, through the electro-motor by which the train was driven. The power generated being calculated so as to be more than sufficient to maintain the maximum speed required, the latter could be regulated, through a balanced centrifugal governor driven off one of the motor shafts, this governor being provided with a slider which was capable of engaging springs so that the electro-motor should be cut out when a certain pre-determined rate of speed had been attained, whilst at a still more accelerated velocity a brake would be applied.

To prevent excessive sparking, a device consisting of a double spring was used, one member of which was arranged to form contact with one terminal, before contact with the other one should be broken. The same object, however, could also be attained by throwing in excessive resistances.

In order to prevent a following train from approaching too close to a preceding one, an electro-magnet was mounted on the top of each post or support, which electro-magnet had a lever armature, and a reaction spring to act as a circuit closer. The wire which excited the electro-magnet came from the contact made by the before-mentioned switch lever that had been pushed aside, or the coupling piece that had been thrown out of action by the passing of the electro-motor, and belonging to the preceding insulator. At such time as the armature remained in contact with the core of the electro-magnet, the preceding section of the wire rope-way would be in electrical communication with that in use. This con nection would be maintained between the sections for a certain distance behind the train, quite independently, it might be, of the movable coupling pieces, and the break in the electrical circuit between the sections, which was absolutely necessary in order to convey electric power to a following train, would consequently not be in existence.

Another arrangement sometimes employed in place of the above consisted of two conductors placed side by side and divided into sections, so that the break in one would be at the middle of the other. At such time as no train was passing, the current crossed backwards and forwards between the conductors by movable coupling pieces. A passing train, however, established connection through its electro-motor by moving each switch lever in succession, and immediately before each switch broke the cross connection, it made contact with a supplementary wire which worked the electro-magnet of the switch last opened back into its normal position, and for an instant cut out the electro-motor; the line circuit being never broken, no sparking could take place. The same electro-magnets might be arranged to form a blocking system, but a supplementary wire and electro-magnet were preferably employed for this purpose.

## Improved Systems of Telpherage.

The system was subsequently improved by Professor Jenkin, more particularly as regards the driving mechanism, and that for regulating the speed of motion, that is to say, for securing a constant rate of motion, and a definite minimum interval.

To regulate automatic electrical transport it is desirable, in the first place, to adjust the speed of each vehicle or train to a given rate, so that the line may be filled with vehicles all running as nearly as may be at one rate, but inasmuch as it would be obviously impossible to make this adjustment of speed absolutely perfect, and since accidental delays or stoppages may occur, it is necessary to check any vehicle or train which may approach too near the preceding train. The minimum distance behind the preceding train at which the check would be applied will in the following description be spoken of as the minimum interval.

As regards the means for securing a definite minimum interval. In effecting the transport of goods or passengers along ropes by the aid of electricity, it is desirable to regulate automatically the distance between successive trains or single vehicles, and this distance may frequently be much smaller than would be allowable in the case of trains or vehicles driven by steam.

A number of methods have been proposed by which the minimum distance would be determined by automatic blocking, some form of key or electrical switch being required to be fixed at frequent intervals along the line, the mechanism of these electrical switches or keys being worked partly by the direct mechanical action of a passing train and partly by electrical devices. The following are methods for determining a minimum space interval between trains or single vehicles which require no special keys, switches, or other moving parts fixed on the line, and are especially advantageous in cases where the interval between the trains or vehicles is to be small, inasmuch as they avoid the multiplication of the delicate and complex pieces of apparatus requiring frequent inspection.

These improvements are applied to the series system, which has been previously mentioned, in which system a single main conductor broken up into sections of equal length is used, and the train is of the same length or nearly so, as each section.

The desired block or minimum interval is secured, in this system, by fixing a series of detached insulated wires or other conductors, called block wires, alongside the main conductor. In the simplest arrangement these wires are each of the same length as the sections into which the main conductor is divided, and they begin and end at the breaks in the main conductor. A rubber is provided at each end of the train placing each block wire temporarily in connection with that part of the main conductor which is alongside it. The connection at the leading end of the train will be hereinafter designated the leading cross connection, and the connection at the trailing end of the train the trailing cross connection. The trailing cross connection is a simple wire or other conductor. The leading cross connection includes the coil of an electro-magnet the armature of which is held down when a current passes, and is released when no current flows, and the movement of the armature when a current passes is made to arrest the train. This electro-magnet will be called the block electro-magnet. This could be effected in various well-known ways; for instance, mechanically, by allowing a break to act; or electrically, as by cutting out the electro-motor on the train, or by short circuiting this electro-motor. These or any other desirable electrical or mechanical actions could be produced directly, or they could be produced indirectly by the help of a relay. So long as only one train be on a given section the block electro-magnet remained inoperative, but if the leading end of a train were to enter on a section still occupied by the trailing end of a preceding train, a derived current would flow through the trailing cross connection of the preceding train, the block wire, and the leading cross connection of the following train, the electro-magnet of the following train then acting to arrest that train until the preceding train had cleared the block wire, and the following train would then be driven as before. This method of blocking is clearly shown in the diagram, Fig. 66, wherein the numerals 1, 2, 3, 4, indicate sections of the main conductor to be connected and disconnected by switches; $a^1$, $a^2$, $a^3$, $a^4$, the block wires each of the same length as the sections into which

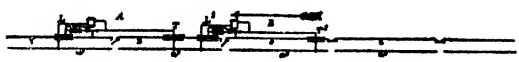


FIG. 66.—Blocking Arrangement for a Telpher Line on the Series System.

the main conductor is divided; A and B two trains; L and L¹ the leading cross connections; and T and T¹ the trailing cross connections. The train B is blocked by the action of a derived current flowing through L¹, $a^2$, and T.

This simple form is especially applicable to telpherage where the line is intended to convey light vehicles following each other in rapid succession. The block wires will check any train which tends to gain on those which precede, but, if by accident a train were to stop so that its trailing wheel had only just entered upon a new section, the following train might run into it, for the second train experiences no check until it enters on the section which is occupied by the trailing wheel of the preceding train. In order, therefore, to prevent this, and to make the block act with a minimum interval equal to that of one section of the main conductor, each block wire is extended or prolonged behind the section it is intended to protect, and is made twice the length of one section of the main conductor. To facilitate description the half of each block wire at which the train first arrives will be called the second half of the block wire, the other half of the wire the first half.

The leading cross connection rubber puts the main conductor into connection with the second half of one block wire. The rubber of the trailing cross connection puts the next section of the main conductor into connection with the second half of the next block wire, and also with the first half of a third block wire.

The leading cross connection comprises the block electro-magnet, and when a following train overtakes a preceding one, so far as to enter on the section next to that occupied by the trailing wheel of the preceding one, a derived current flows from the main conductor through the leading cross connection of the second train, a block wire, and the trailing cross connection of the first train, back to the main conductor. This current would continue to flow if the second train be forced forward into the same section of the main conductor as is occupied by the trailing wheel of the first train, but the block wire employed will have changed.

In the arrangement shown in the diagram, Fig. 67, the block is made to act with a minimum interval equal to the length of one section of the main conductor. As in the first diagram, 1, 2, 3, 4 represent sections of the main conductor, $a^1$, $a^2$, $a^3$, $a^4$, $a^5$, block wires twice the length of one section of the main conductor, and arranged by crossing, as shown in the diagram, to make the connections with the leading and trailing cross connections L and T. The train B is in this case blocked by a derived current through T, $a^3$, and $L^1$.

This device may be likewise employed to make the minimum interval twice, three times, or $n$ times, the

FIG. 67.—Blocking Arrangement for a Telpher Line with Minimum Interval equal to one Section of the Main Conductor.

length of each section of the main conductor, for which purpose three, four, or $n+1$ block wires will be required respectively.

Should a polarised electro-magnet be used as the block electro-magnet, the trailing cross connection may be that which connects the conductor with only one block wire, while the leading cross connection with the polarised electro-magnet must then be in connec-

FIG. 68.—Blocking Arrangement for a Telpher Line with Inverted Block Wires and Cross Connections.

tion with $n$ block wires. Thus, in the diagram Fig. 68 an inversion of the block wires and cross connections is shown, which is an obvious equivalent for the arrangement last explained. The loop in the leading cross connection in this and some of the following diagrams represents the block electro-magnet which would require to be polarised, that is to say, only to cut out the motor when the current runs in one direction, otherwise in the position shown in Fig. 68 both the trains would be stopped.

Analogous cross connections, rubbers, and block wires are used when the general system of transport is on the parallel arc system, in which there are two main conductors maintained at different potentials, and successive trains or vehicles are driven by electro-motors, each of which establishes a connection between what may be termed the positive and negative main conductors, the wires of the successive electro-motors being consequently all in parallel arc between the main conductors.

To apply the arrangement in its simplest form to the parallel arc system, the block wires must be a series of equal insulated conductors, which may be of any length, and each block wire overlaps that which follows and that which precedes it to the extent of half their length. The half of each block wire which precedes the other looking in the direction in which trains pass, will be designated as the first half, the other portion as the second half.

The trains or vehicles which require to be protected have each two rubbers insulated one from the other and placed opposite each other at the same place in the train or vehicle. One rubber is always connected with the positive main conductor and the other with the negative main conductor, the one called the leading rubber, although it does not precede the other, putting one main conductor in connection with the second half of a block wire alongside the main conductor; the other rubber, called the trailing rubber, putting the other main conductor in connection with the first half of a block wire alongside the main conductor. These two connections are called the leading and trailing cross connections, and the leading cross connection includes a block electro-magnet which acts in a manner analogous to that required for the series system. When the leading rubber of one train enters on the second half of a block wire, the first half of which is connected with the trailing rubber of a preceding train, the block electro-magnet will arrest the following train, for a current will then flow from one main conductor to the other, from the trailing rubber of the preceding train, through the block wire and the leading rubber of the following train, and when the preceding train leaves the block wire the following train will be freed.

An application of block wires to the ordinary

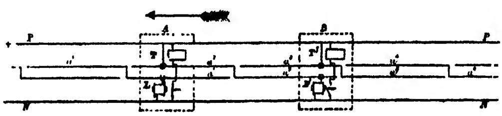


FIG. 69.—Blocking Arrangement for a Telpher Line on the Parallel Arc System.

parallel arc system is shown in the diagram Fig. 69. P and N here indicate two continuous conductors, the motor which propels the train being driven by a current passing from P to N by means of rubbers which connect the motor with these rails or mains conductors. A and B represent two trains supposed to be driven in this way in the direction shown by the arrow. $a^1$, $a^2$, $a^3$, $a^4$ indicate block wires which are arranged as shown, and the length of which is not determinate, but which block wires are habitually equal to one another, the first part of one being necessarily equal to the second part of that which precedes it. T, $T^1$, and L, $L^1$ indicate the trailing and leading cross connections, and it is obvious that the train B will be blocked by a current flowing through T, $a^2$, and $L^1$. It is usually necessary in each block wire to insert some piece of material such as carbon to prevent the passage of an excessive current.

When this simple method is applied to telpherage, however, it does not form a perfect guard to the preceding train, for if the following train were to overshoot one-half of a block wire the block would be removed and a collision might occur. Thus in the diagram under consideration it will be seen that should the train B, notwithstanding the block, move on until $L^1$ leaves $a^2$ and touches $a^1$, the block will be removed; the block is therefore in this plan only operative for one-half of the block wire.

The above defect might be practically obviated by making the block wires so long as to render this overrunning highly improbable, or the block could be rendered more efficient by increasing the number of the block wires. For example, if there be three overlapping block wires instead of two, each block wire will then consist of three parts, which may be denominated the first, second, and third part respectively. The leading cross connection will then join one main conductor, through a block electro-magnet, to the third part of each successive block wire, and the trailing rubber of the train will join the other main conductor to the first part of one block wire, and the second part of the next. A following train will then be blocked by a preceding one, so long as the second train is passing over two-thirds of the length of a block wire, and will only be released when within one-third of that length. An arrangement in which a third block wire is used is shown in the diagram Fig. 70.

When four overlapping block wires are used the block electro-magnet will act for a distance equal to three-quarters of each block wire, and, by increasing the number of the block wires, the fraction of the length during which the block will operate can be increased at will. A simple method of carrying out this arrangement consists in placing the block wires obliquely between the two parallel main conductors, and letting the trailing rubber be broad enough to make contact with all but one.

Both in the case of the parallel arc and series systems, the block will be quite independent of the direction in which the preceding train may have been moving, but if the preceding train has been moving back upon the following train, although it will stop any following train, it will not itself be stopped. In

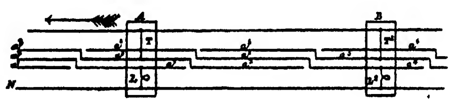


Fig. 70.—Blocking Arrangement for a Telpher Line with a Third Overlapping Block Wire.

telpherage, however, this backing is practically never required, and, moreover, a backing train can be automatically prevented from running into or colliding with a following one, by arranging the mechanism so that when any train runs backwards, a block electro-magnet will be automatically inserted in what is properly the trailing cross connection.

A method of effecting this automatic insertion is shown diagrammatically in Fig. 71, and consists in having two frictionally geared wheels, A, B, lightly pressed together, A being driven by the movement of the train so that its motion will be reversed when the train backs, and B having a contact piece by which the block electro-magnet will be cut out, or put in.

The friction will lift this contact piece during forward motion, but will depress it should the movement of the train be reversed.

To work the parallel arc system with a single rope for up trains, and a single rope for down trains, the single conductor which forms the circuit must be crossed alternately from the up to the down line, so

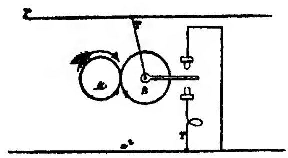


FIG. 71.—Arrangement of Block Electro-Magnet for Preventing Train from Backing into a Following One.

that when the conductor charged positively is on the up side, the conductor charged negatively will be on the down side, and *vice versâ*. The up and down lines are divided into sections of equal length, as in the series system, and the train should be of the length of one section or nearly so, the leading end of the train being, say, on a positive section and the trailing end

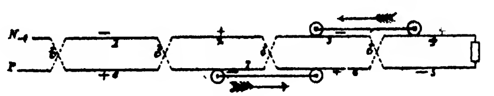


FIG. 72.—Arrangement of Conductors for Admitting of a Line on the Parallel Arc System being Worked with a Single Rope.

on a negative section. Fig. 72 illustrates diagrammatically a special arrangement of conductors by which the parallel arc system may be worked with a single rope for up trains, and a single rope for down trains. N, P are two continuous conductors insulated from one another, and maintained at different potentials by a dynamo, as in the arrangements shown in

Figs. 69 and 70. These conductors are divided into equal lengths, as indicated at 1, 2, 3, 4, and 5, 6, 7, 8, so supported that 1, 2, 3, 4, &c., will form a single road along which a train having a row of single wheels can run, and 5, 6, 7, 8, &c., will form a second similar road. The electrical cross connections, 1, 7, 3, 5, which cause N to be a continuous conductor, and 8, 2, 6, 4, which cause P to be a continuous conductor, are shown by dotted lines. These conductors or ropes are supported by brackets and insulators on each side of ports placed at $c^1$, $c^2$, $c^3$, $c^4$, &c.

From the above it will be clearly seen that if trains, similar to those first described in the case of the series system, are placed on these roads or ways, they will

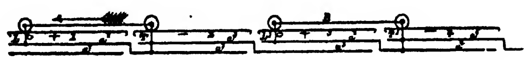


FIG. 73.—Modified Arrangement of Block Wires for Line with Alternate Positive and Negative Sections.

be driven by the currents flowing through the rubbers and move from one section to the next, as from 4 to 3, or from 6 to 7, one rope being used as an up line, and the other as a down line. A piece of solid insulated material to carry the weight of the wheels is usually placed at the gaps, so that the wheels in passing shall not short circuit the conductors, or the same danger may be provided against by insulating the wheels, and lifting the rubbers by a cam at the moment of passing the gaps. This plan of driving combines the advantage derived from the use of the single rope with the advantage resulting from the absence of all switches or keys.

Fig. 73 is a diagram showing another method of applying the block wires to this arrangement of driving, where only one line, with the sections alternately positive and negative, is used. The action by which the train B will be blocked in this example will be obvious from previous descriptions.

In the plan shown in the diagram, Fig. 74, the train A will block the train B when the leading wheels of B reach a section already occupied by the trailing wheels of A. In this arrangement the leading and trailing cross connections are both placed at the beginning of the train, but the current through T does not pass through L.

The two latter arrangements may be combined, and may be reduplicated so as to protect sections situated further back.

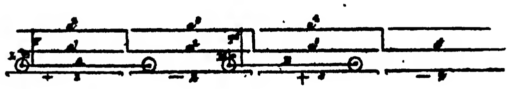
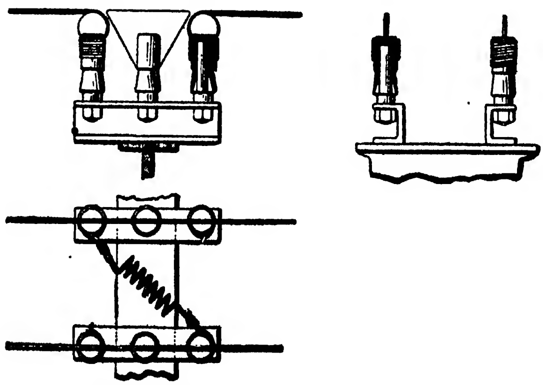


FIG. 74.—Blocking Arrangement with the Leading and Trailing Cross Connections placed at beginning of the Train.

By the term block electro-magnet is meant any contrivance set in action by the passage of an electrical current, and having for its object the checking or arresting of the electro-motor with its train or single vehicle. The simplest method of checking the train is by cutting out the motor on the parallel arc system, and by short circuiting it on the series system, or in the latter system the motor may be cut out and the circuit joined up without short circuiting the motor, as shown in the diagrams, and the current may be employed to start a subsidiary electro-motor which puts on a brake which is released when the blocking current ceases, the block being put in action by means of block wires and trailing and leading connections, and no switches, keys, or electro-magnets being used on the permanent way.

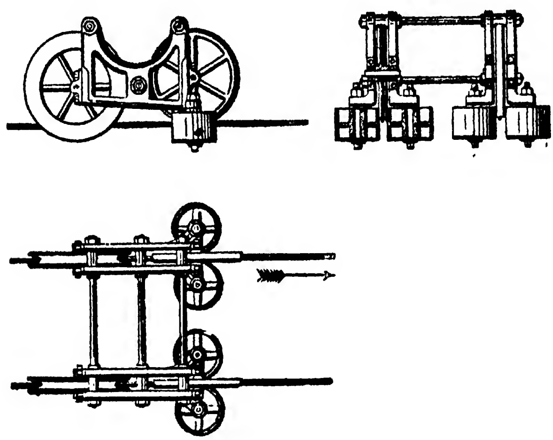
In cases where the carriers or vehicles are arranged for the conveyance of persons, the system of blocking allows the guard to see when he is overtaking another train or is being overtaken by it. This he can do by observing whether a current is flowing through either cross connection. The guard can also test the action of his own mechanism by temporarily completing a circuit through leading and trailing rubbers and block



FIGS. 75, 76, and 77.—Method of Mounting Block Wires in Line on Telpher System. Side, End, and Plan Views.

wires. For instance in Fig. 69 if, by a supplementary insulated metal rubber, the guard joins $a$ and $a^2$, his train should instantly be checked by a current passing through the two main rubbers of the block system, and the block electro-magnet. It is evident that this mode of checking trains would form a convenient brake as well as a mode of testing the apparatus.

A convenient method of mounting the block wires is shown in side and end elevation, and in plan in Figs. 75, 76, and 77. Metal supports are fixed by the side of the line, on posts, or brackets, in any convenient position. Each of these supports carries six vertical pins, and on these pins pottery ware insulators are fixed. The heads of these insulators are cylindrical, and they are arranged to receive metal caps. To four of these caps the block wires, which are strained between the supports like ordinary telegraph wires, are securely attached. As shown in the illustration, the wire is led down over the curved head of the cap,



Figs. 78, 79, and 80.—Contact Maker or Circuit Closer for Line on Telpher System. Side, End, and Plan Views.

and is twisted and securely fixed around the body. A cross connection couples two of the wires together, whilst the other two terminate at the support. The contact maker or circuit closer is provided with bearers to lead it without concussion from wire to wire.

This circuit closer takes the form of a carriage, and it is shown in side and end elevation and in plan in Figs. 78, 79, and 80. It consists of metal frames connected by crossbars, and provided with metal wheels which run on the wires, and the carriage serves electrically to connect the wires on which it stands. Side rollers are also provided to prevent the carriage running off the wires. A light rod not shown in the drawing forms the connection between the carriage and the train drawn by the electro-motor.

This device connects together the parallel wires on which it stands, which is what is desired in one of the connections. In the other connection, however, it is required that contact should be made with the wires on one side only, and for this purpose the carriage is so made as to insulate its two sides, the crossbars not being fixed directly to the metal side frames, but to insulators like those shown in Figs. 75, 76, 77, which are carried on vertical pins provided for them upon the side frames.

To regulate the speed at which the train when unchecked will be propelled, that is, to provide means by which the speed may be maintained constant or adjusted independently of variations in the resistance to be overcome, or in the source from which the electrical energy is derived, or in the circuit, or in the number of trains to be driven by that circuit, without the use of a relay or an electro-motor, the device illustrated in Fig. 81 is employed. A, B, C are three wheels so geared that A will drive B, and, if the axis of B remains stationary, B will drive C. If, however, the motion of C be resisted by a force exceeding a given adjustable amount, C will remain at rest and the axis of B will be displaced, an arrangement in fact of differential gearing. C is connected with some resistance such as that due to a fan, a centrifugal brake, a pendulum, or the flow of water through an orifice, so regulated that the resistance will increase with the speed at which the machine to be governed happens to be running.

Another resistance is also opposed which may be constant or nearly so to the motion of the axis of B, and to the latter is attached a make and break piece or commutator, or other means of controlling the electrical current supplied to the motor, in such a way that, so long as the axis of B remains at rest, the full driving current will pass through the motor, but when, with the increase of speed, the resistance to the motion of C also increases, and the axis of B moves, this motion will break the circuit, or reverse the connections, or move the brakes, or short circuit the motor, or throw in resistance, in fact the motion of B is used to effect any desirable change in the electrical connections.

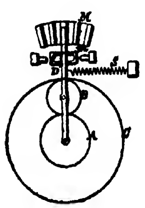


FIG. 81.—Device for Regulating the Unchecked Speed of Trains on Telpher Line.

Upon the speed decreasing so that the resistance to the motion of C will have again fallen to the normal amount, the axis of B will return to its former position under the action of a spring or weight, by which its motion is resisted, and the current will be supplied as before.

Preferably the axis of B is arranged to move between two fixed stops placed at a considerable distance apart, in order to avoid continual interference with the circuit when running at nearly the normal speed, and the make and break piece attached to B is so arranged as only to alter the circuit when near to either of the two ends of its travel.

Referring to the illustration; A and C are the pitch lines of two wheels externally and internally gearing with the pinion B. A and C are concentric but not on same shaft, or one of them is mounted loosely upon the shaft. F is centred on the arm D which is pulled against a stop by a spring S. A is driven by the motor to be controlled. C is resisted by any resistance which increases with the speed, as by a fan, centrifugal arrangement, or water governor, so that at a certain speed the arm D will begin to rotate round the centre, and will work a make and break piece *m*, or a commutator M, or any other electrical device. The make and break piece *m* may have a slot in it, as shown, so that the pin indicated only moves it to or fro when the arm D is near the end of its travel.

As a rule it is desirable that the change of mechanical resistance to the motion of C should change largely with a small change of speed at the critical point, and a simple plan for effecting this change is by making C drive a brake governor *m* of the type devised by Sir William Thomson, in which a revolving weight is normally clear of an external rim, but at a given speed overcomes the resistance of a spring so far as to come in contact with this rim, and as it were put on a brake by means of the friction it creates.

The effect produced by a governor of the above description is neutralised when the speed of the machine falls back to the normal desired speed or a little below it. Cases arise, however, in which this is undesirable, as some permanent change may occur in the driving current, or in the mechanical resistance to the driven electro-motor, as when the gradient of a telpherage line changes, and this renders a permanent readjustment of the electrical mechanism desirable. The simple slot arrangement described above and applied to any centrifugal governor will effect this purpose, or it may be performed automatically and with great accuracy by the governor shown in Fig. 82. A, B, C form a train of wheels so arranged that A drives B, and B drives C, or *vice versâ*, C may drive B.

and B will then drive A. Upon B being turned in one direction it produces an electrical change tending to increase the speed of the motor, and upon B being rotated in the reverse direction this change will be undone.

A centrifugal governor is so arranged that when the speed falls below a certain point an arm presses against a smooth pulley or surface connected with A, and so drives B in one direction. When, on the other hand, the speed rises above a certain point, the same, or another arm, presses against a smooth pulley or surface connected with C and drives B in the opposite

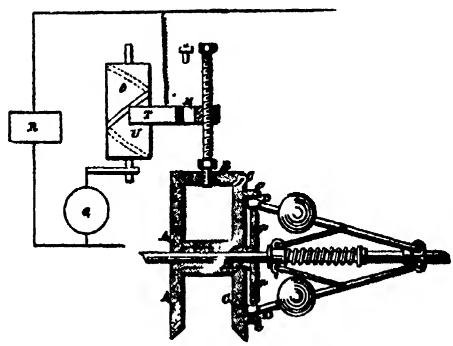


FIG. 82.—Governing Arrangement for Train on Telpher System.

direction, but when the speed remains intermediate between the two limits the arm, or arms, are clear of A and C, and B is left at rest. B may thus be employed to shunt or cut out a motor, to throw in or out an electrical resistance, or to adjust brushes, or to cause an electric field to apply a mechanical or electrical brake, or to produce any change, mechanical or electrical, which regulates the speed, and in this manner a permanent change may be effected, which will not be undone when the motor is brought back to the desired speed. The change may if desired be effected in the driving dynamo instead of in the receiving motor, or in both.

The governor is preferably employed in the following manner. Connected mechanically with the machine to be controlled is a regulating drum or disc divided into two parts insulated from each other, and a rubber pressing against this drum or disc alternately makes one of two connections. When one connection is made the motor will be driven by the current, but when the other connection is made the current will be diverted or interrupted so as not to drive the motor.

The driving and non-driving connection will be of a length dependent on the position of the rubber relatively to the drum, and this position is shifted in the way above described by the wheels A, B, and C.

In the drawing the rubbing pieces D, D, of the balanced centrifugal governor, bear against the smooth surfaces *c* or *a*, as the velocity happens to be above or below that required. When the speed is exactly right or normal, these rubbing pieces will run clear, and in the latter case the wheels A, B, C will all be at rest. If the speed becomes excessive, the wheel B will be worked by C; if, on the contrary, the speed be insufficient, the wheel B will be driven by A. The shaft of B has a screw by which a nut M is worked backwards or forwards and is used to produce the desired change. A desirable method of effecting this required change is shown diagrammatically in Fig. 82. The insulated rubber or brush T actuated by M rubs on the insulated pieces O and U of a cylinder, as shown. O is insulated and U is connected by another rubber with one terminal of a motor Q, the other terminal of the motor being joined to a dynamo R, the other pole of which is connected with the rubber or brush T.

It will be seen that if, at one end of the cylinder, the piece U goes all round, and at the other end the piece O goes all round, and at intermediate points the proportions between O and U gradually vary, the time during which the current will be admitted to the motor will depend on the position of the rubber or brush T, which latter will be determined by the governor. The connections for O and U can easily be varied to suit other arrangements in which an absolute break might not be desirable. In fact the well-known system of cutting off the current for a fraction of each revolution is employed, but in such a manner that the cut-off shall be undisturbed so long as the speed remains constant, but may be permanently varied by a temporary change of speed so as to be different at different times although the speed may be the same. With this arrangement, if the resistance to the motion of the motor should decrease tenfold below the maximum which the motion could overcome, when the current was on continually, a slight increase of speed would screw M along until the current was cut off for about nine-tenths of each revolution. When the speed had fallen to the desired amount in consequence of the withdrawal of the current, the rubber or brush T would be left in its new position and the machinery would run at the old speed notwithstanding the great alteration in the conditions.

Fig. 83 shows another arrangement of the governor by which the desired permanent change can be effected, in which a well-known mechanical equivalent is substituted for the three wheels previously used. In this arrangement the bevel wheels A and C are connected by a sleeve, or form part of one piece which is capable of a small motion along the shaft under the influence of a balanced governor, and if the speed becomes excessive the bevel wheel A will drive the bevel wheel B in one direction, whilst should the speed become deficient or decrease, the bevel wheel C will drive B in the opposite direction. When, however, a predetermined rate of speed is maintained, both the bevel wheels A and C will remain clear, and B will be at rest.

On attaining the limiting or extreme position, M might be employed to put on a mechanical or electrical brake, as by making contact with the stop *t*, and the governor might in this way be employed to put a brake on a train, if it continued to run too fast even after the whole electric current had been cut off. This effect would, however, be produced instantly, or almost instantly, after the current had all been withdrawn.

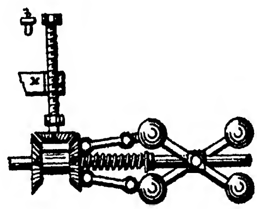
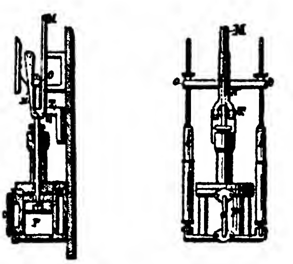


FIG. 83.—Modified Form of Governing Arrangement for Train on Telpher System.

To afford additional security against the chance of trains or vehicles being overtaken by those which follow, any apparatus may be used by which a mechanical or electrical brake will be set in operation to arrest a train or vehicle whenever the time during which the motor of this train or vehicle has been deprived of the driving current, by any one of the means which have been already described, exceeds a definite length, and by which the brake will be at once removed when the driving current begins to circulate. The effect of this arrangement will be that when the block or governor acts merely to control the speed, no power will be wasted in unnecessarily resisting the motion of the train or vehicle, but if this train or vehicle runs past the block for more than a definite number of seconds, so as to be in danger of overtaking the preceding train or vehicle, or of running too fast, then its motion will be checked not only by the withdrawal of motive power, but also by the action of a brake.

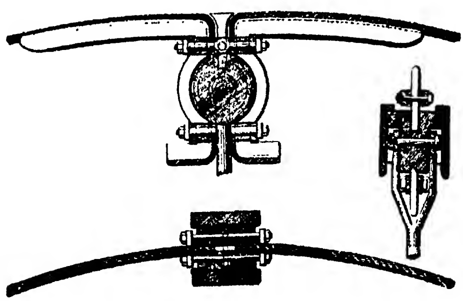
Figs. 84 and 85 illustrate in elevation and section one way of carrying out the above arrangement. The piece M is in this case actuated by the governor so as to move downwards when the velocity increases beyond the normal; when this motion has reached the limit at which the speed can be controlled, as already described, by entirely cutting off the current, a wedge piece or stop Q will actuate a catch N so as to release the crosshead O. This crosshead will be then pulled downwards by springs $s^1$, $s^2$, its motion being resisted by a dash-pot P, or other contrivance which will delay or retard the motion for the desired time. After the lapse of this time, the crosshead O will fall down nearly to the stop Q, and will make contact at T, so as to apply an electrical brake. The time between the release of the catch and the arrival of the crosshead O at its limiting position may be for instance thirty seconds, yet when the speed falls, the stop Q attached to M will, as soon as the latter begins to move back again, break the contact at T, and so take off the electrical brake. On M rising it will again set the catch N. It is obvious that the contact at T may be employed in many ways to arrest the train, indeed the mere mechanical pressure



Figs. 84 and 85.—Brake Arrangement for Trains on Telpher System. Elevation and Vertical Section.

of the springs $s^1$, $s^2$, on a quick running wheel, instead of T, would in most cases form a sufficiently powerful brake. The dash-pot P should be so arranged as not to resist the upward movement of the crosshead O, and were a fan employed instead of the dash-pot, it should be driven by the descent of the crosshead O, and not by its ascent.

To enable wire ropes to be used as the insulated conductor, a special form of insulator capable of resisting a great strain, and also of allowing the ropes to rock on the point of support, and so relieve the



FIGS. 86, 87, and 88.—Insulator for Use on Telpher Line. Side Elevation, Plan, and Cross Section.

supports from inconvenient strain, is employed. This insulating device wherein the ends of the wire ropes are secured in bent wrought-iron pieces clipped to a circular insulator free to rotate round a centre pin, is clearly illustrated in side elevation, plan, and vertical cross section in Figs. 86, 87, and 88, in which the insulating parts are indicated by cross-hatching.

Horns of metal having shallow grooves on their upper sides intended to receive the wire rope, are bent round the main insulating piece, and again bent back. The rope passes between this metal horn and the main insulating piece, and is also bent back and is secured by being lashed to the horns. The horns are bent as shown in plan when the post is to stand at an angle, and the two horns are clipped together by straps which are insulated from them by insulating packing pieces. A piece of metal fixed in the main insulator helps to bridge the gap between the ends of the wire ropes.

A pin, which is supported by a fork, serves to carry the main insulating piece, and the surface of the latter near the pin is shielded from the wet by the outer pieces shown in the vertical cross section, and by the form of the main piece itself. The rocking action on the pin prevents any undue strain from coming on the support.

By forming the insulator over the pin in the shape shown, good insulation is ensured for the whole system from the earth, and the resistance across the packing pieces is rendered sufficient.

A number of improvements have been made by the Consolidated Telpherage Co., of New York, and lines designed on their system are extensively employed in America. One of the chief characteristics of the aerial system of this firm is what is known as the Unit System. The results of numerous trials, and many experiments, with various methods, have convinced them that this is both the most flexible system and the one which most successfully fulfils the greatest number of conditions, and that this fact is capable of practical demonstration.

Fig. 89 is a plan view showing a carriage or telpher truck composed of a single or one unit, and termed a single unit telpher. As will be seen from the drawing* the device is of simple construction, and

* See also Figs. 134 and 136, pp. 173 and 176.

it consists broadly of the combination with a suspended car of a shaft rigidly fixed to the supporting wheels, the electric motors located on each side of these wheels having their revolving armatures also rigidly fixed on the shaft. The motors are provided with a

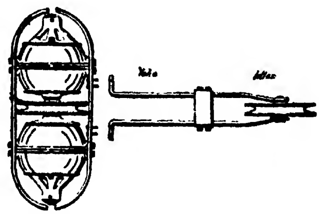


FIG. 89.—Single Unit Telpher Carriage or Truck.

frame by which they are connected together, and combined with the yoke and trailing or idler wheel constitute a single unit telpher truck.

Fig. 90 is a similar view to Fig. 89, illustrating a carriage or telpher truck consisting of a double

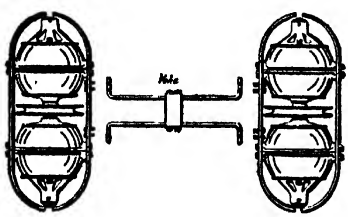


FIG. 90.—Double Unit Telpher Carriage or Truck.

unit, or two units. It consists as shown simply of two units combined by a yoke, the second unit in the double unit telpher taking the place of the trailing or idler wheel of the single unit telpher.

# CHAPTER IV

EXAMPLES OF INSTALLATIONS OF WIRE ROPE-WAYS ON THE RUNNING OR ENDLESS ROPE SYSTEM AT: WORKS IN FRANCE—MILL IN MEXICO—FURNACES AT MIDDLESBROUGH—WATER WORKS IN NORTHUMBERLAND—PIER AT THE CAPE DE VERDE ISLANDS—PIERS IN NEW ZEALAND—QUARRY AT EMBOROUGH—QUARRIES IN INDIA—CEMENT WORKS IN BRAZIL—MINE IN CUMBERLAND—PRINT WORKS IN LANCASHIRE—CHEMICAL WORKS IN NORTHUMBERLAND—MILL IN YORKSHIRE—LINOLEUM WORKS IN MIDDLESEX—SUGAR PLANTATIONS IN DEMERARA, JAMAICA, MAURITIUS, MARTINIQUE, ST KITTS, GUATEMALA, &c.—CUSTOM HOUSE IN MAURITIUS—BEETROOT FARM IN HOLLAND.

## Installation at Works in France.

THE following are brief descriptions of several installations on the Gourjon* running-rope system of wire rope-way erected in France. In this system but one endless cable is used moving round two pulleys in the same vertical plane, the full skips being carried to their destination by the lower portion upon which they are suspended at equal distances apart, and the empty skips returning on the upper portion. Motion is imparted according to circumstances, by force of gravity, or by power, or partly by gravity and partly by power in a regular and continuous manner.

One of the installations in question which was erected at Teil, has a length in a horizontal direction

* A detailed description of the Gourjon system of wire rope tramway will be found in the *Annales des Ponts et Chaussées*, vol. xiv., 1887, p. 604.

of 1,558 feet, and as the difference of level is only 81 feet 8 inches, a certain amount of help has in this case to be given by power from the motor at the works, to assist the action of gravity.

The carrier buckets, or receptacles, which are of sheet iron, are suspended from the cable at intervals of 111·5 feet apart, weigh when full 110 lbs., and travel at a speed of 5·75 feet per second, or at the rate of about 3·92 miles per hour.

The installation cost £100, and the traffic upon the line is 70 tons a day, the cost of transport being 3·11 pence per ton-mile.

An installation erected at St Imier, near Grenoble, is considerably longer, following the windings of a valley for 8,200 feet, or over 1½ mile. The two portions in the intervals between the end pulleys are supported at the same level by pulleys mounted on posts or standards located about 500 feet apart.

The cable used is made of steel wire on what is known as the Excelsior system, and has a diameter of 0·67 inch; whilst a cable made of a like number of round wires, and of the same weight per fathom, would have a diameter of 0·906 inch, or very nearly 1 inch in the latter case against a little over ½ inch in the former case. The reason of this is owing to the absence of interstices in the case of the Excelsior make.

The cost of this line was £520, the traffic is 50 tons a day, and the cost of transport 3·75 pence per ton-mile.

Another short temporary installation put up at Alzon was used for conveying blocks of stone for masonry work connected with a railway. The line crossed a valley 1,579 feet wide, having a difference of level between the termini of 474·5 feet.

In this case the excess power due to gravity could be used for moving a second cable which had a span of 88 feet, and a rise of 48 feet, by connecting it with the upper pulley, so as to carry the stone from the quarry to the pulley placed at the edge of the valley.

The uncoupling of the carriers was effected automatically, but the coupling had to be done by hand, which caused some delay; 130 tons were transported per day at a cost of 14·4 pence per ton, the cost of cartage being double.

The cost of the line was much increased by a failure to calculate the tension of the cables, and a carelessness in erection, which caused accidents to take place on commencing work which otherwise might have been avoided, and but for which the outlay would have been only £480, and some £2,400 would have been saved in the transport of 52,330 cubic yards of material.

In another installation two portions were on the same level, and passing over vertical pulleys at the end of the track were directed at an angle of from 20° to 25° to a winding drum, located horizontally at a slightly lower level, thus greatly facilitating the uncoupling and coupling of the carriers.

This line was designed for a distance of 2,214 feet, with a fall of 242·75 feet; the cost was estimated to be £440, and 72 tons of cement were to be carried down daily at a slow rate of speed from the kilns to the works, the cost of transport being estimated to be 2·1 pence per ton, instead of 10½ pence per ton, which latter was the price of cartage. The capacity of such a line could, however, easily be raised to 100 tons daily by somewhat accelerating the speed, and the empty carriers could be used for conveying up coal to the kilns. The drum or pulley at the end of the line would then have to be connected with the motor

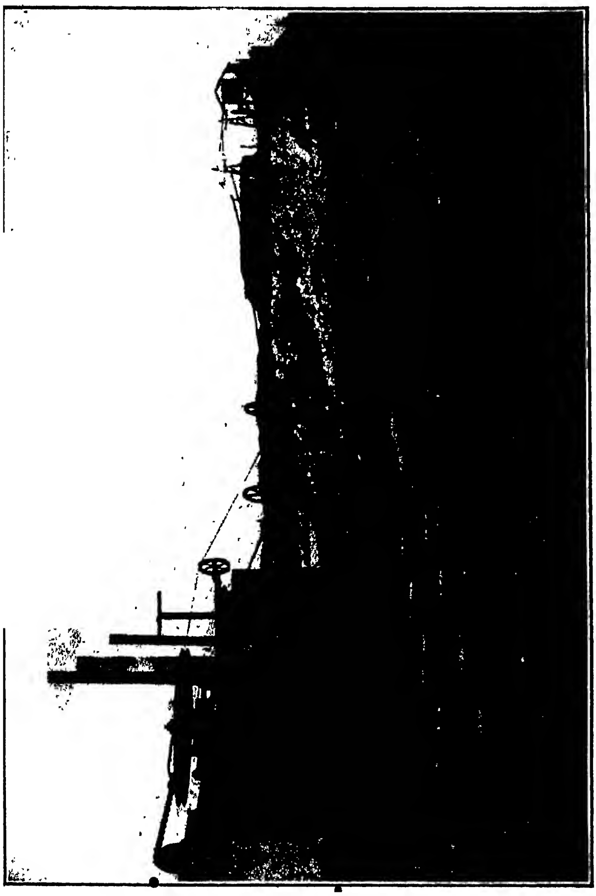


FIG. 91.—Installation at Furnaces at Middlesbrough: General View of Line.

of the works, so as to lower or raise the power due to gravity according to circumstances, and produce a uniformity of speed.

## Installation at Furnaces at Middlesbrough.

Fig. 91 is a general view of a line on the Carrington running-rope system designed by Bullivant & Co. Ltd., and erected at Middlesbrough for removing the slag dump from mine furnaces so as to admit of the land being used for other purposes. The illustration shows the unloading terminal in the distance and the loading terminal in the foreground, the tension gear being in the rear of the latter. The capacity of this rope-way is 15 tons per hour, and the buckets have a capacity of 4 cwt. each. The line extends the entire length of the heap that it is desired to level, the discharging terminal being situated at the highest point and the loading terminal at the lowest point. The latter terminal rests upon a short section of rail, and is gradually moved towards the unloading terminal as the material is removed from before it, without necessitating any change in the gear. The slag is brought to the loading terminal in the buckets to be placed on the running rope.

From the unloading terminal the slag is discharged into a crusher, from which it is delivered into a rotary screen which separates the material into four grades, each of which is received by a separate compartment of a hopper, and is loaded into trucks on a railway.

## Installation at Water Works in Northumberland.

An installation on the same system has been constructed by Bullivant & Co. Ltd., for the Newcastle and Gateshead Water Works, Wylam-on-Tyne, Northumberland, for the purpose of carrying cement, bricks, and other material for the construction of conduits, &c., in connection with new works, and also for carrying coal for the Company's pumping station, which is situated some distance short of the main discharging terminal.

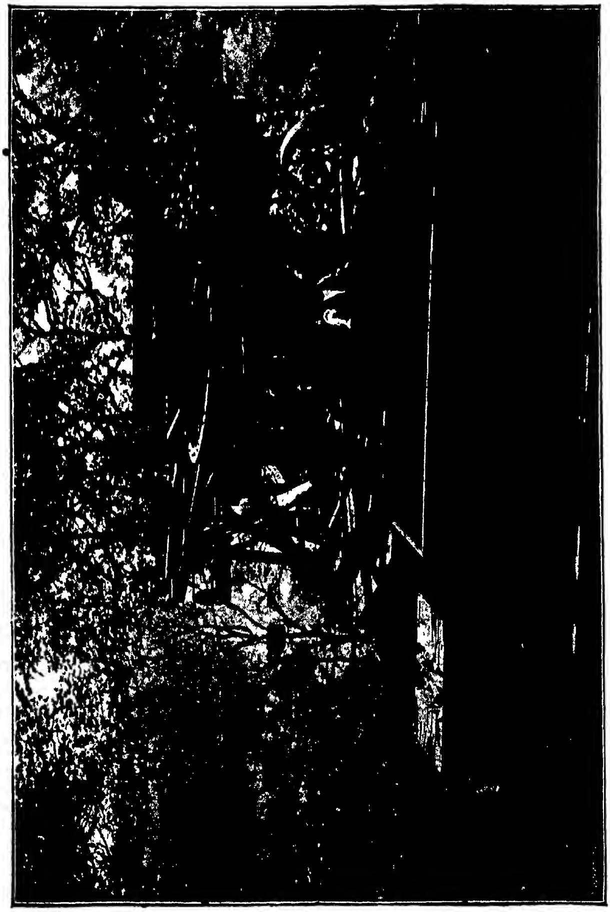


FIG. 92.—Installation at Water Works, Northumberland : General Unloading Station.

The total length of this line is 1,800 feet, and it has a capacity of 20 tons per day. The posts or standards are constructed of steel, and of the type having four legs. The longest span is one of 490 feet where the line passes over the River Tyne. The loading station at the tensional terminal is so arranged that it could be placed between two lines of rails, for which purpose the gauge from that point to an adjacent angle frame is one of 6 feet, whilst from the latter to the upper or general unloading terminal it is one of 8 feet. The construction of this upper terminal is illustrated very clearly in Fig. 92, which also shows one of the posts or standards and a portion of the line with a carrier coming and going. The materials are here unloaded into contractors' waggons which latter are made up into trains and are taken to the new works. The driving power is supplied by an ordinary undertype pattern of portable steam engine, and only two men are required to operate the line.

An intermediate unloading terminal is provided at the pumping station at which a loaded carrier can be stopped during its transit, and the contents discharged through a chute into a hopper for loading the works waggons. On one side of the loading station a hopper is provided for loading the carriers with coal from the railway trucks, whilst on the other side a chute is arranged for filling the carriers with bricks from the trucks on another siding.

## Installation at a Mill in Mexico.

An installation on the running-rope system at Plomosos * in the State of Sinaloa, Mexico, for conveying wood to a mill, has a total length of 10,115 feet, or not far from 2 miles. The upper terminal of

* A very full description, from which this abstract has been made, will be found in the *Transactions of the Technical Society of the Pacific Coast*, San Francisco, 1890, p. 113.

this line is at an elevation of 3,575 feet above the lower one, thus affording a good example of a line on the running or endless rope system of comparatively short length, with a considerable difference in level between the termini. The spans were respectively 935, 863, 104, 1,378, 977, 1,935, 410, 1,066, 771, 833, and 433 feet, at first, making in all 9,705 feet; but to this length 410 feet were subsequently added between spans 8 and 9, when the vertical turn sheaves were replaced by horizontal ones, raising the length of the line to 10,115 feet, as before mentioned. The outline of the ground is shown in the section, Fig. 93,

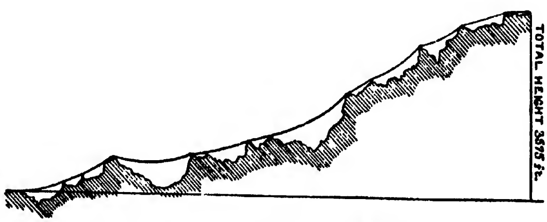



FIG. 93.—Installation at Mill in Mexico: Section.

from which it will be seen to be of a very rugged nature.

Most of the frames of the standards were constructed of hewn timber, because this latter material was easily available, thus counterbalancing the slight advantage which sawn timber is stated to possess for the purpose.

The framework of the upper terminal consists of balks of timber 8 inches square.

The run of the loaded carriage for taking up the slack of the rope is limited to 54 feet, the counterweight gear being at the lower terminal only, and the other end of the rope being firmly anchored. The slack of the rope is taken up when the splices are renewed from time to time.

The intermediate posts or standards were first constructed single, but in many places they were afterwards braced, by having X-shaped frames erected round them.

The counterweight gear is mounted in a four-post tower 24 feet in height, the weight box being 5 feet square and 3 feet deep.

In lines of this description the travelling carrying rope is supported on suitable sheaves or pulleys, which latter are mounted vertically upon the ends of cross arms fixed on the posts or standards at a sufficient height to clear all surface obstructions. At the termini the rope passes around sheaves or pulleys set horizontally. These sheaves are either grip or plain sheaves as the case may require, grip sheaves being used where power has to be supplied to the rope, or to prevent slipping where brakes are employed to regulate the speed, in which case the brake wheel or drum would be attached to the upper side of the grip pulley.

The rope employed is a $\frac{13}{16}$ inch diameter steel plough rope made at the California Wire Works from special steel obtained from Germany, giving a tensile strength of 300,000 lbs., or about 133 tons $18\frac{3}{4}$ cwt. per square inch.* The carrier frames or hangers are secured to the rope by means of a type of carrier box or fastening, known as the Hallidie clip, a description of which has been already given.†

The transport of this rope was, owing to the rugged nature of the country to be traversed, a matter

Tensile strength given in the paper, which seems to be excessively high.

† See pp. 25-27.

of very serious difficulty. It was accomplished by dividing the rope into ten lengths, each length made up into seven coils, with an intermediate length of 10 feet, and each of the coils in each length was loaded upon the back of a mule, the entire train being composed of seventy mules, and three men being provided to each seven mules, or thirty men altogether.

In transporting a wire rope in this manner the coils should be made up as small as possible, say not over 24 inches, so as to enable them to be secured to the pack saddles.

During the conveyance of the section of rope to the upper terminal an accident occurred which was productive of very considerable delay, and demonstrated the difficulties attendant upon the operation. The head mule, at a point where a rise immediately followed a steep descent, started to take the rise with a rush until checked by the rope, which threw him backwards over the bank, he taking two other mules with him, and had not the last of these caught on a tree, the rest of the train would have followed. The path being cut out of the mountain side, and so narrow as not to admit of turning a mule, or even of unloading its pack, the coils which had gone over the bluff were fished up, uncoiled, and carried a quarter of a mile by hand. The rope was, however, badly kinked through the mishap.

This kinking of the rope is indeed one of the chief dangers to which this method of transport renders it liable, the parts thus damaged being usually the intervening lengths between the mules. The result of a bad kink in the rope is that the wires of the strands on the concave side of it will shortly give out when in use.

Screw-down brakes were employed upon this line

As regards the cost of transport, this was found to be reduced by about three-fourths by the use of the rope-way; 5,100 cords of wood delivered to the mill as fuel costing before the existence of the rope-way £12,670, whilst 5,900 cords delivered by the rope-way only cost £3,392—a saving of £9,278, and an additional supply of 800 cords of wood, being thus effected by the use of the latter.

## Installation as a Pier at the Cape de Verde Islands.

The following is a description of another installation on the running-rope system, erected in the Cape de Verde Islands, at Messrs Cory Brothers & Co.'s Coal Depôt.*

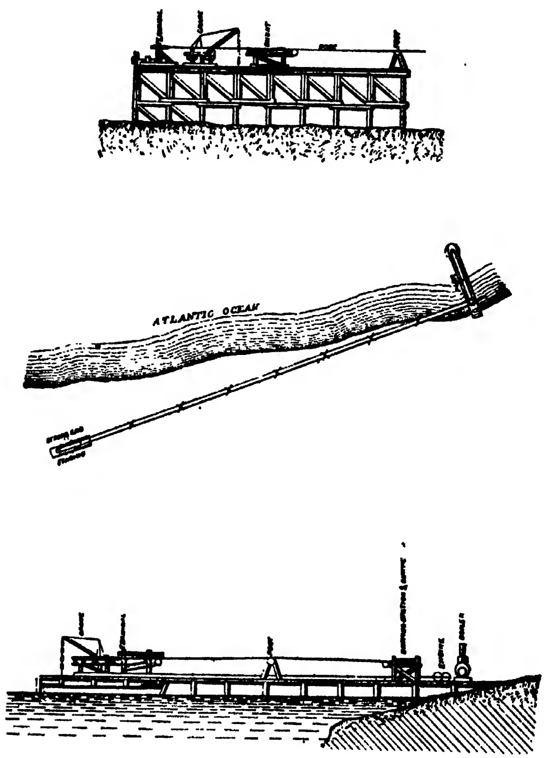
The total length of this line, which is illustrated in Figs. 94, 95, and 96 in plan and elevations, is 1,200 feet, of which length about 960 feet extend along the beach, and about 240 feet at right angles to the longer section to the end of the pier, where the coal is received and despatched.

The rope-way was required to be able to carry 15 tons per hour in either direction, and the motion of the rope to be utilised in working cranes at each terminal for raising or lowering coal.

The coal is brought to the pier in bulk in barges from the colliers, and the buckets of the aerial or wire rope-way are lowered into the barges by a crane, and when filled are again raised, and sent off on the wire rope-way to the depôt at its farther end, where a quantity of about 10,000 tons is usually stored.

* A full description of this installation, which was designed by Mr W. H. Carrington, M.I.C.E., Consulting Engineer to Messrs Bullivant & Co. Ltd., will be found in the *Minutes of Proceedings of the Institution of Civil Engineers*, vol. lxv., pp. 299-309

To supply the steamers calling at the island, the coal is filled at the store into bags holding 2 cwt. each, which bags are raised by a crane to the level of the




FIGS. 94, 95, and 96.—Installation as a Pier at the Cape de Verde Islands: Plan and Elevations.

wire rope-way, and are carried by it back to the barges at the end of the pier.

The driving gear with its steam engine is placed at the point where the two sections of the wire rope-way meet at right angles. It consists of a massive wooden frame, carrying an upright shaft fitted at its upper end with two drums, each 8 feet in diameter, lying one on the top of the other, the ropes of the sections passing round these two drums, and being driven by them. At the lower end of the vertical shaft bevel gear is fixed, by which the motion of the steam engine is communicated to the drums. The steam engine by which the requisite power is supplied is one of 16 horse-power nominal, having two cylinders and a surface condenser. The boiler is of the horizontal multitubular type, working at a pressure of 60 lbs. per square inch. The usual shunt rails allow the loads to pass round the angle which is formed at this point.

The terminal at the end of the shorter section on the pier-head carries the horizontal drum round which the tramway rope passes, and a long horseshoe-shaped rail. On this frame is also mounted a crane, having a radius of 17 feet, and worked by shafting from the engine. This crane is manipulated by a friction clutch, actuated through a lever on the top of the frame, on which the driver stands, from which position he has a clear view of the work going on below. Four carrier buckets or receptacles, each holding $2\frac{1}{2}$ cwt., are lifted at a speed of 80 feet per minute, and are deposited on to a deck alongside the terminal frame. These buckets or receptacles are then pushed singly down an inclined plane, the arrangement being such that they engage themselves on the hangers, which, with their saddles, carry them on the line rope. In a similar way the empty buckets or receptacles arriving, or the sacks for delivery, are detached and lowered into the barge.

The terminal at the end of the longer section at the coal store is placed on a wooden platform, shown in elevation in Fig. 94, about 20 feet above the ground, and 120 feet long. At the end of this platform, situated the farthest from the driving station, is placed a horizontal drum 8 feet in diameter, carried on a strong wooden frame, round which drum the line rope passes, and which can be drawn back when required to take up any extension. The motion of the rope actuates the drum, which by a pair of bevel wheels turns a square shaft extending along the centre of the platform for its whole length. A crane of similar construction to that on the pier-head is placed on this platform in front of the terminal, and can be moved from end to end, deriving motion from the line rope through the square shaft at any point. The jib of this crane is long enough to enable loads to be hoisted on either side of the platform, and to be put down just behind the travelling shunt frame, which stands about 15 feet in front of the crane, and which is arranged to slide up and down the full length of the platform in conjunction with it. Thus the sacks of coal, having been raised from the ground, are placed at the foot of the shunt stage, by which they are, having been first hung on the hangers, pushed on to the moving rope, and transported to the pier.

When coal is being brought to the store, it is tipped into an inclined shoot out of the buckets while they hang on the rail of the moving shunt.

It will be seen from the arrangements above described that the coal can be hoisted out of the barge at the pier-head, transported to the terminal depôt, and delivered into the store, where it is duly put into sacks for re-delivery to steamers; and when this is required, the sacks of coal can be lifted up to the rope-way, a height of 20 feet, transported to the pier-head, and deposited into the barges.

The rope is supported on the longer section by seven posts or standards, which are fixed on the beach, and are of the usual construction, and about 15 feet high. These posts or standards carry bearing pulleys 2 feet in diameter, grooved to fit the wire rope, which latter is of crucible steel with a breaking strain of 16 tons, and is run at a speed of 3½ miles per hour.

This rope-way, though it was only designed to lift and carry 15 tons per hour, has on emergencies conveyed more than 25 tons in an hour.

The cost of the maintenance of the rope has been a halfpenny per ton carried, and that of the machinery also a halfpenny per ton, the chief item in the latter case being the breaking of the buckets or receptacles by rough handling. The cost of labour has been one penny per ton handled, including tipping the coal into the store, and attending the engine. The cost of working the crane and filling the buckets or receptacles in the barge has been about five-eighths of a penny per ton the boiler for supplying steam to the engine consuming 7 cwt. of coal per twelve hours.

The complete cost of the above installation erected on the spot, but exclusive of freight and customs duty, was about £2,500, including the large staging at the depôt and the whole of the woodwork. The erection on the site occupied three months.

## Installations as Piers in New Zealand.

A pier wire rope-way, designed by the same engineer, was constructed at Russel, Bay of Islands, New Zealand, the short section of the line running for about 3,600 feet out into the bay, and the main line from the pier to the mines on the mainland being about 1 mile in length. The terminal at the head of the pier is erected upon an old hulk which is securely moored in position.

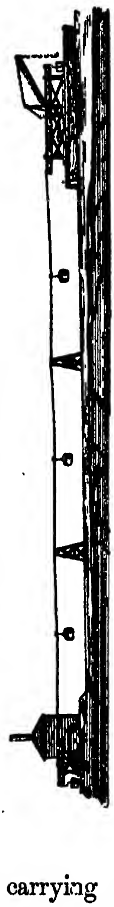


Fig. 97.—Installation of Wire Rope-Way driven by Stationary Engine arranged as a Pier in New Zealand.

Fig. 98.—Installation of Wire Rope-Way driven by Portable Engine arranged as a Pier in New Zealand.

The carrying capacity of this line is about 50 tons of manganese ore daily, with a motive power of 6-horse.

Figs. 97 and 98 show two other arrangements of wire rope-ways on the running or endless rope system arranged as piers, the constructive details of which are

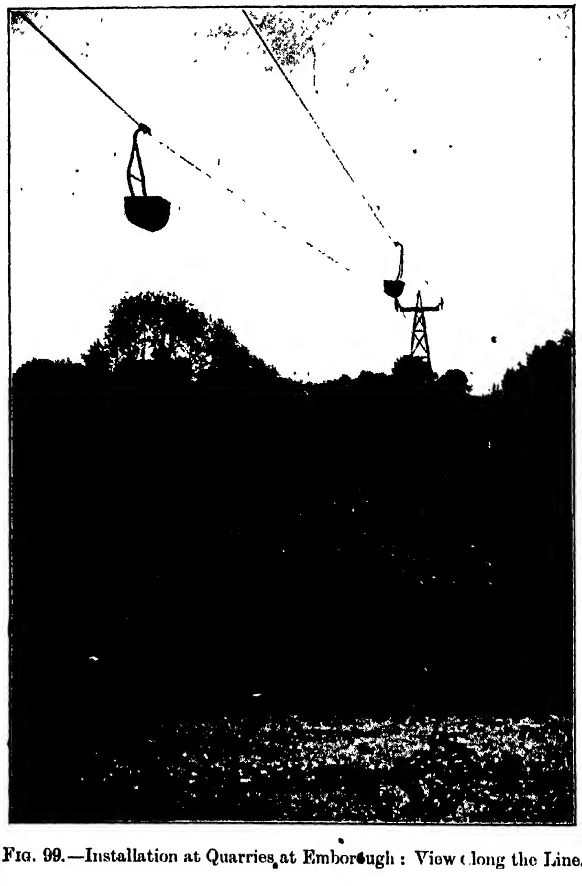


FIG. 99.—Installation at Quarries at Emborough: View along the Line.

practically similar to those already described, modified where necessary, however, to meet the different requirements of each particular case.

## Installation at Quartz and Granite Quarries at Emborough.

Another installation on the Carrington running

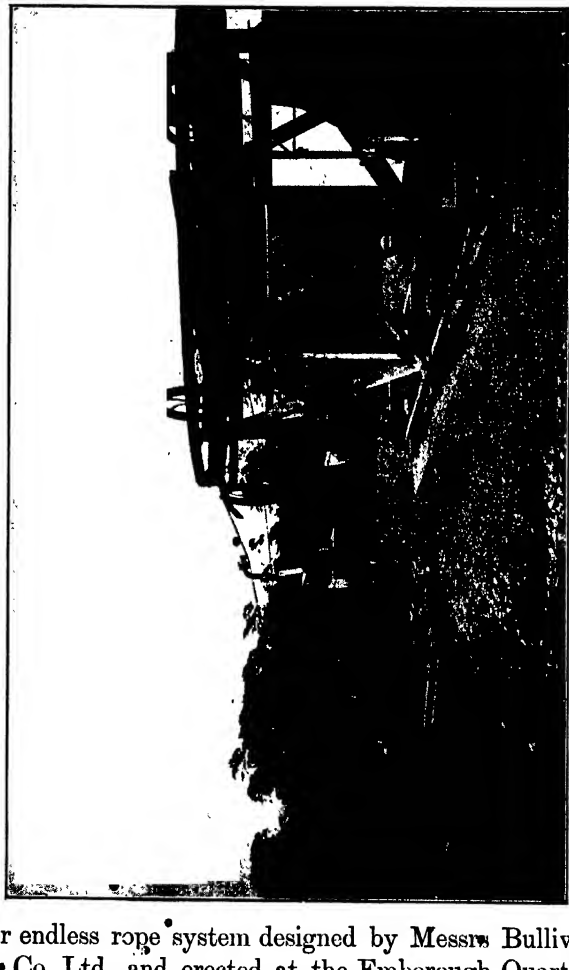


FIG. 100.—Installation at Quarries at Emborough: One of Terminals.

or endless rope system designed by Messrs Bullivant & Co. Ltd., and erected at the Emborough Quartzite Quarries for conveying broken granite and quartz from a new seam to the crushers, is illustrated in Figs. 99 and 100, the first figure showing a view along the line with the carriers coming and going, and the second figure being a view showing the arrangement of one of the terminals and a portion of the line.

The length of this wire rope-way is 3,500 feet and its capacity 25 tons per hour, the weight of the individual loads being 5 cwt. The standards or trestles and terminal frames are constructed of steel, and the longest span is one of 775 feet. Motive power is produced by a Tangye engine, and the carrier buckets are loaded from a hopper through chutes.

## Installation at a Stone Quarry in India.

Fig. 101 shows diagrammatically in plan and section a wire rope-way or cable-way on the Carrington running or endless rope system erected at a quarry in Madras, India, for the carriage of concrete material. This wire rope-way, which has a total length of 15,600 feet, or nearly 3 miles, was supplied to the order of the Indian Government, for the purpose of carrying about 100 to 150 tons of material per working day, for the purpose of constructing a large concrete dam in a very out-of-the-way situation in Madras.

This installation affords a good example of the facility with which a line on the endless-rope system can be made to pass angles of any degree, and admits of surmounting certain constructive difficulties that would prove very difficult to overcome, if not fatal, in the case of any other arrangement.

In the present example, as will be seen from the plan, the line passes three angles varying from 157° to 169°, and, as will be seen from the section, over inclines varying from 1 in 3 to 1 in 4.

Another feature is that the driving power is water, which was found attainable at a point about half-way between the terminals of the line.

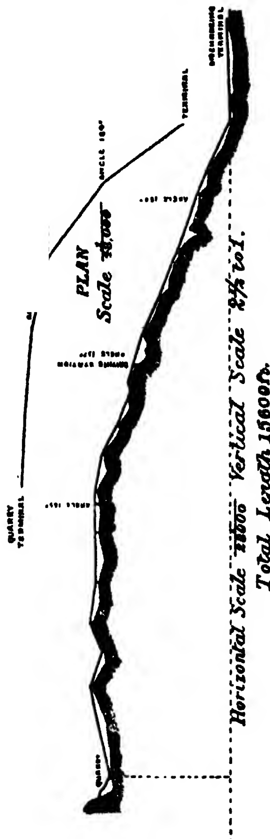



FIG. 101.—Installation at a Quarry at Madras, India: Section and Angle Plan.

The entire line was erected on the spot by native workmen.

## Installation at a Cement Works in Brazil.

Fig. 102 shows in section a wire rope-way installation


Fig. 102.—Installation at a Cement Works, Jundiahy, Brazil: Section.

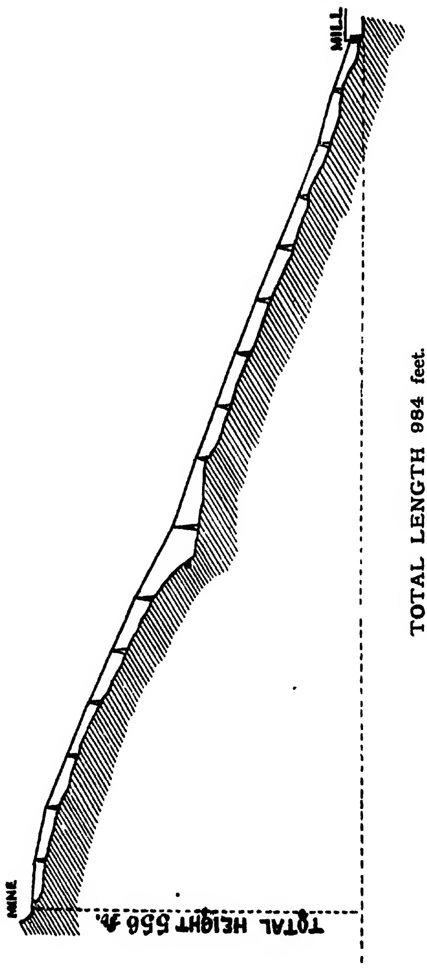



Fig. 103.—Installation at a Barytes Mine in Cumberland: Section.

on the Carrington running or endless rope system put up in connection with a cement works at Jundiahy, Brazil.

The extreme length of this line is 8,961 feet, or about 1·7 mile, and it is capable of transporting some 100 tons of cement in bags per working day of ten hours.

The line passes over extremely rough ground, and changes its direction in two places. At a number of parts the incline is 1 in 3·5, and there are spans of 500 feet.

The bags of cement are carried in water-tight cases made of galvanised iron, and so constructed as to turn over on the release of a catch. The necessary motive power to work the line is provided in this instance by a 14 horse-power engine of the semi-portable type.

This line affords an excellent example, as will be seen from an examination of the section, of the maximum spans and severe inclines which can be satisfactorily worked with wire rope-ways on this system.

## Installation at a Barytes Mine in Cumberland.

Fig. 103 is a sectional view illustrating a short wire rope-way erected at a barytes mine in Cumberland for the purpose of conveying the mineral from the mine, which is located on the flank of a hill, to the mill and dressing floors, which are situated at its foot, at which latter point water-power is available.

The total length of the line is 984 feet, and the difference of level between the mill and the mine is 556 feet, the average incline being 1 in 5.

The water wheel which provides the power for driving the mill also serves for supplying that necessary for working the rope-way, all the power, however, that is required for the latter purpose being a sufficient amount to act as a means of governing the speed and controlling it, as the loaded carriers run down by gravity. The situation of the line and the

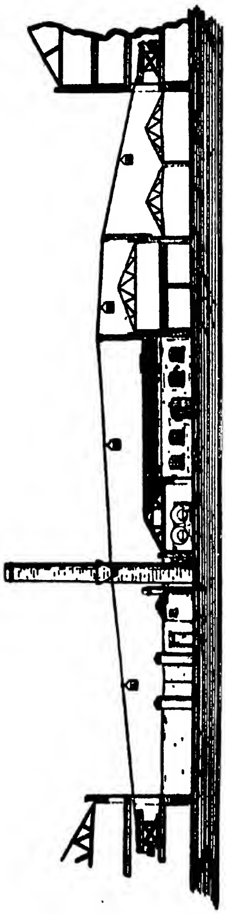


FIG. 104.—Installation at a Print Works in Lancashire: Sectional View.

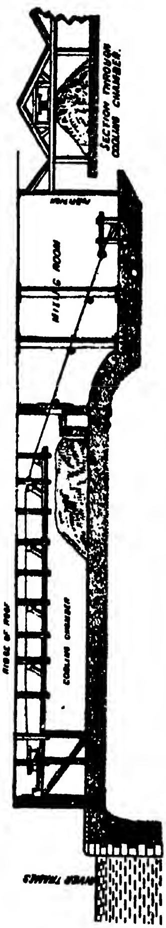


FIG. 105.—Installation at an Artificial Manure Works near London: Sectional Views.

character of the incline over which it is worked are shown approximately in the illustration.

The carrying capacity of this wire rope-way is 100 tons per day.

## Installation at a Print Works in Lancashire.

Fig. 104 is a sectional view showing an installation, on the Carrington running or endless rope system, at a print works in Lancashire. The construction of the box carriers for the textile goods, which usually hold about 120 lbs. each, has been already shown in Fig. 51.*

A number of lines of the above description have been running successfully for a great many years at print works in various parts of the country.

The following are some further examples of installations, on the same running or endless rope system as the preceding, that have been erected at manure, chemical, linoleum, and other works.

## Installation at an Artificial Manure Works near London.

Fig. 105 is a sectional view showing an installation of wire rope-way on the running or endless rope system, erected at an artificial manure works.

The illustrations in both this and the following examples, although only diagrammatical, are sufficiently explanatory to show the general arrangement of the lines, the constructional details being, as already mentioned, similar to those already given.

## Installation at a Chemical Works in Northumberland.

Fig. 106 is a sectional diagram showing the disposition of a wire rope-way on the running-rope system about 1,500 feet in length, erected at a chemical works in Newcastle-on-Tyne, Northumberland.

This line, as will be seen from the illustration, passes throughout its course over buildings, dwelling-

* See p. 60.

houses, and yards full of workmen. It starts from a point near the centre of the works, close to the spot

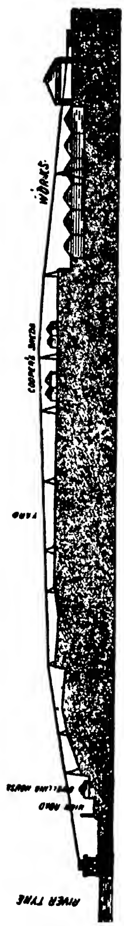


Fig. 106.—Installation at a Chemical Works, Newcastle-on-Tyne: Sectional Diagrammatical View.

Fig. 107.—Installation at a Mill, Huddersfield: Sectional Diagrammatical View.

Fig. 108.—Installation at a Linoleum Works, Staines: Sectional Diagrammatical View.

at which the refuse or waste material is produced which it is desired to remove by means of the rope-way. The line first rises at an incline of about 1 in

10 over intervening sheds, passes close over the buildings containing the coopers' workshops, and then descends until it reaches the terminus on the bank of the River Tyne, where a staging about 30 feet in height is provided on the quay side, from which the refuse material or waste product can be emptied into barges lying in the river.

The engine for supplying the motive power is placed upon the above-mentioned staging.

The carrier buckets or receptacles for the refuse or waste product contain about 3½ cwt. each, and the carrying capacity of the line is about 120 tons per working day.

This wire rope-way was run, transporting the above amount of material daily, for about eight years, when the works were closed.

## Installation at a Mill in Yorkshire.

Fig. 107 is a similar view to the last, showing an installation on the running-rope system at a mill in Huddersfield, Yorkshire.

This wire rope-way, which is about 900 feet in length, is used for the purpose of transporting coal from a coal mine belonging to the company to their boiler house, where four large boilers are supplied.

The coal is conveyed in carrier buckets, which contain 1 cwt. each, and which are filled from a shoot at the colliery. On reaching the boiler house the loaded carriers pass from the rope on to a shunt rail suspended from the roof, along which rail they run over the hoppers of the mechanical stokers, one of which is fitted to each boiler. These hoppers are adapted to contain 2 tons each, which amount is a supply sufficient for half a day's consumption of each of the boilers, and one hour's running of the rope-way is required to effect the filling of the above.

The driving gear for operating the rope-way is located against the wall of the boiler house, 2 horse-power being required to work the line when fully loaded.

The cost of carriage, including renewals and labour, has been found to be about twopence per ton transported.

## Installation at a Linoleum Works in Middlesex.

Fig. 108 is also a similar view to the preceding, showing a short wire rope-way on the running-rope system of about 600 feet in length, erected at a linoleum works near Staines, Middlesex, where it is used for the conveyance of coal from the railway siding up to the upper floor of one of the workshops, from which it is shot into the adjacent boiler houses.

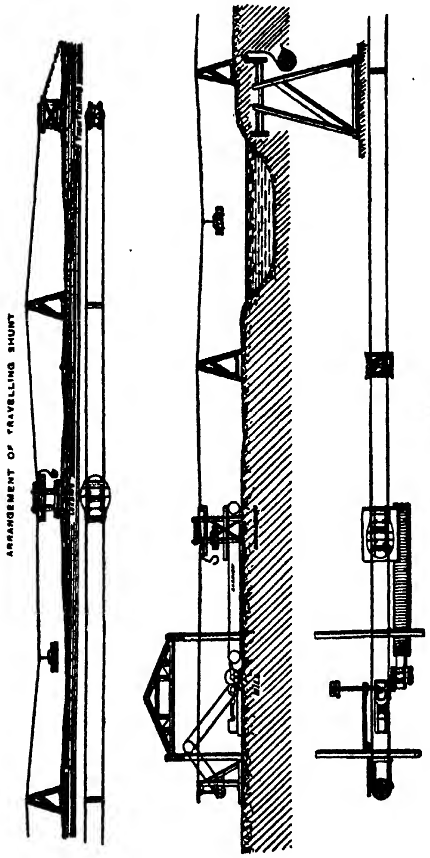
During its course this line passes over a river and many of the workshops and roofs. The incline is about 1 in 5, and the coal is carried in loads of 1¼ cwt.

Motive power is in this instance water, and is supplied by means of a turbine which also serves for driving other machinery.

## Installations on Sugar Plantations.

The usual arrangement adopted on sugar-cane plantations in Demerara, Jamaica, Mauritius, Martinique, St. Kitts, Guatemala, Australia, &c., will be readily understood from the arrangements diagrammatically illustrated in Figs. 109, 110, 111, 112, and 113 in plans and elevations.

These lines are usually driven by power, that of the cane mill being generally utilised, but in some cases they. are run by gravity. The canes are deposited from the carriers, a description and illustration of which has been previously given,* at the mill, and




Figs. 109, 110, and 111.—Installation on a Sugar-Cane Plantation: Travelling Shunt, Mill Terminal, and Arrangement of Driving.

loading can be effected at any point on the line by means of the travelling shunt shown in elevation and plan in Fig. 109.

* See p. 61

The plan view, Fig. 112, shows an arrangement in which several wire rope-ways driven from the same point are arranged to discharge on the same cane carrier, and is one extensively adopted in the Mauritius.

Fig. 113 shows a portion of a line and of a simple form of post or standard for an endless running rope-way for carrying sugar cane, in side and end elevation.

A large number of installations of these wire rope-ways for the carriage of sugar cane are at work in the island of Mauritius alone, the lines varying in length from 1 mile to 4 miles, and transporting from 100 to 200 tons of sugar cane per working day.

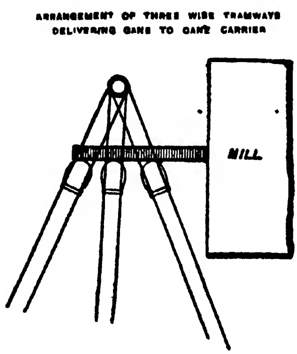



Fig. 112.—Installation on a Sugar Plantation: Junction of Three Lines.

A great advantage which this system of carriage by wire rope-ways affords is, that the canes are delivered in a continuous stream direct on to the cane carriers, and in quantities that are at no time large enough to demand redistribution in feeding the mill, the small individual loads of about 2 cwt. of canes each following one another in rapid succession, so that the quantity delivered can be easily regulated to a nicety by the man engaged in discharging the carriers.

Further advantages derivable from the system are: That canes can be brought from different parts of an estate by one or more wire rope-ways, thereby admitting of readily mixing different lots of canes previous to crushing in the mill. The canes can be transported over other growing or unripe canes, as well as across any rivers or canals or other obstructions lying in the route. The earth is not in any way beaten down as is the case through the treading of mules, horses, or oxen, and the passage of carts, when carting is resorted to, or even with the use of portable ground tramways, or railways, and canes can be brought, moreover, from estates lying on high ground which are inaccessible to ordinary roads, thereby rendering valuable land which would otherwise be practically useless. Cane can be carried more cheaply than by carting, one man being sufficient to discharge up to 150 tons of cane per ten hours, and besides those loading the cane carriers or hangers one man only is required at the despatching terminus.

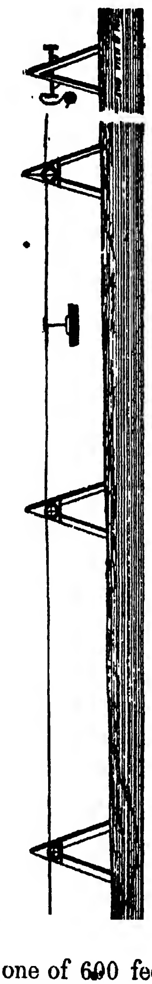


FIG. 113.—Installation on a Sugar Plantation: Portion of Line and Standard.

In many cases it is found to be convenient to employ a combination of cartage with wire rope-way transport, the canes being brought to certain points along the line by the carts, at which points they are loaded and forwarded to the mill on the wire rope-way.

## Installation at the Custom House in Mauritius.

A wire rope-way on the endless or running-rope system: of 3,000 feet in length, the longest span being one of 600 feet, is at work at Port Louis in the island of Mauritius for the carriage of bags of sugar and puncheons of rum to the Custom House.

Loads up to 600 lbs. in weight are transported on this line.

## Installation on a Beetroot Farm in Holland.

On large beetroot farms wire rope-ways are extensively used for carrying off the crops and delivering them to points from which they can be despatched either by rail or ship to the sugar factories.

A good example of an installation of this description is to be found in one designed for the Netherlands Land Enclosure Company for carrying the crops, and for the conveyance of other materials on their estate at Fort Bath, which consists of land that has been reclaimed from the sea.

This line is about 1 mile in length, and has a carrying capacity of 50 tons daily, the produce being conveyed in baskets containing about 100 lbs. each. The power is supplied by a 6 horse-power portable engine.

The line is so constructed that it can be taken down and put up again in a fresh place in one day, by the aid of twenty men, provided the distance to cart the materials composing the rope-way does not exceed 5 miles.

# CHAPTER V

EXAMPLES OF INSTALLATIONS OF WIRE ROPE-WAYS ON THE FIXED CARRYING-ROPE SYSTEM AT: SUGAR PLANTATION IN AUSTRALIA —CHALK PITS IN FRANCE—MINES IN SPAIN—FURNACES IN BELGIUM—SAW MILLS IN SCOTLAND—BLAST FURNACES IN HUNGARY—CEMENT WORKS IN FRANCE—LEAD MINES IN FRANCE—GAS WORKS, LONDON—SAW MILLS IN ITALY—ITALIAN ALPS—FORTIFICATIONS, GIBRALTAR—WATER WORKS, CAPE TOWN—PIER IN SOUTH AFRICA—SUGAR FACTORY, HONG KONG—MINE IN JAPAN—TELPHER SYSTEM IN SOMERSETSHIRE AND SUSSEX—TELPHER SYSTEM IN AMERICA.

## Installation on Sugar Plantation in Australia.

FIG. 114 is a view from the loading station of a wire rope-way on the fixed-rope system, worked by gravity, on a sugar plantation in Australia. The line consists of a single span 5,016 feet long with a 540 feet drop to cane punts in the river below, the capacity being 5 tons of sugar cane per hour, the individual loads being 2 cwt.

Wire rope-ways of this type operated by gravity, and where the loaded carriers are suspended from trucks or runners and are allowed to run down at a high speed on a fixed rope, are known as shoots; they are applicable with advantage wherever the nature of the ground admits of this method of working. The loads may be from 1 cwt. to 4 cwt., and spans up to 7,000 feet can be worked without intermediate support. The loads being suspended from runners which are allowed to run down the carrying rope uncontrolled, some arrangement is provided for breaking the shock of the arriving load. The speed of the runners as they approach the lower terminal, can be regulated by

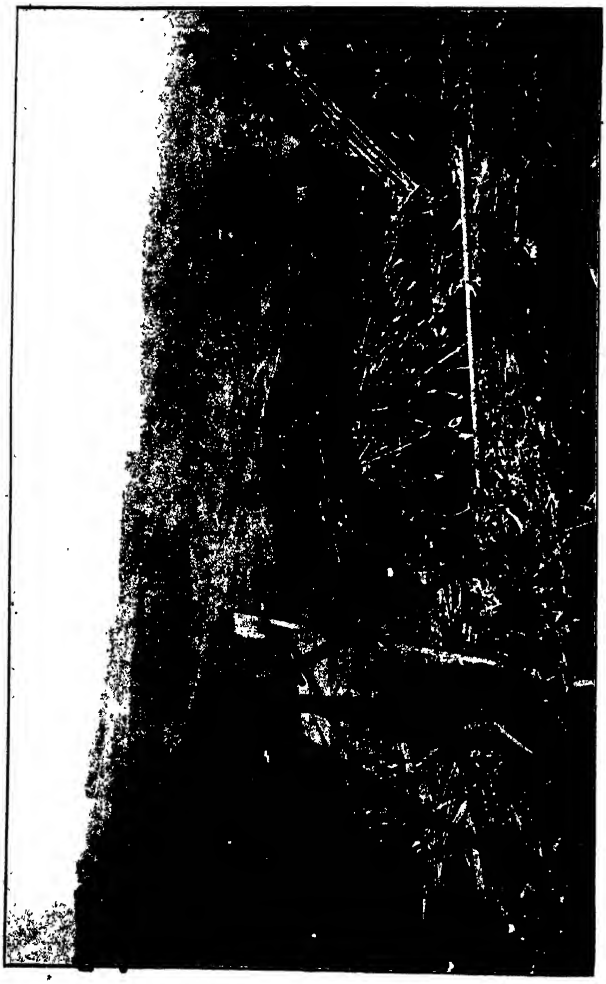


FIG. 114.—Installation on a Sugar Plantation in Australia: View of Line from Loading Station. (*Bullivant & Co. Ltd.*)

adjusting the sag of the carrying rope, and the breaking or cushioning of the shock may be effected by a crude arrangement of a heap of brushwood or other suitable material at the lower terminal, or a more complicated arrangement of buffer may be provided. In the above installation a buffer for breaking the blow of the arriving bundles of canes and a curved shunt for conveying them over a punt in the river are provided.

## Installation at Chalk Pits in France.

A simple system of aerial transport by wire ropes on the fixed carrying-rope system is described by A. Hauet,* which is said to have been in use for about thirty years at the chalk pits near Paris for conveying the chalk for short distances of from 500 to 820 feet in length.

Two carrier wire ropes, $\frac{3}{4}$ inch in diameter each, are arranged parallel to each other, and act as ways or lines, the one for the ascent, and the other for the descent. These ropes are suitably secured to any available support at one terminus, and are placed under tension at the other terminus by the aid of a large T-headed bolt, passed through a block of timber held by an anchor carriage, constructed of angle-iron and of wrought-iron plate, and heavily loaded.

The load is suspended from each of the carrier ropes or cables by means of a truck or traveller having a frame of triangular form, in which are mounted two 8-inch grooved pulleys adapted to run upon the rope, a suspension hook being provided for the attachment of the carrier receptacle.

An endless wire rope of $\frac{3}{8}$ inch to $\frac{1}{2}$ inch in diameter, according to the load to be dealt with,

* See *Revue Générale des Chemins de fer*, October 1888, p. 227, for further particulars.

and running on grooved pulleys of 4 feet diameter mounted at the ends of the line, is connected to this apparatus through a short length of chain. The carrier receptacles or buckets provided for conveying the materials have a capacity of from 3½ to 5 cubic feet.

The loaded carriers descend by gravitation, carrying with them the endless hauling rope which draws up the empty buckets. A friction wooden brake block, or when the gradient exceeds 15 per cent., a steel brake, serves to arrest the motion when the carriers arrive at their destination.

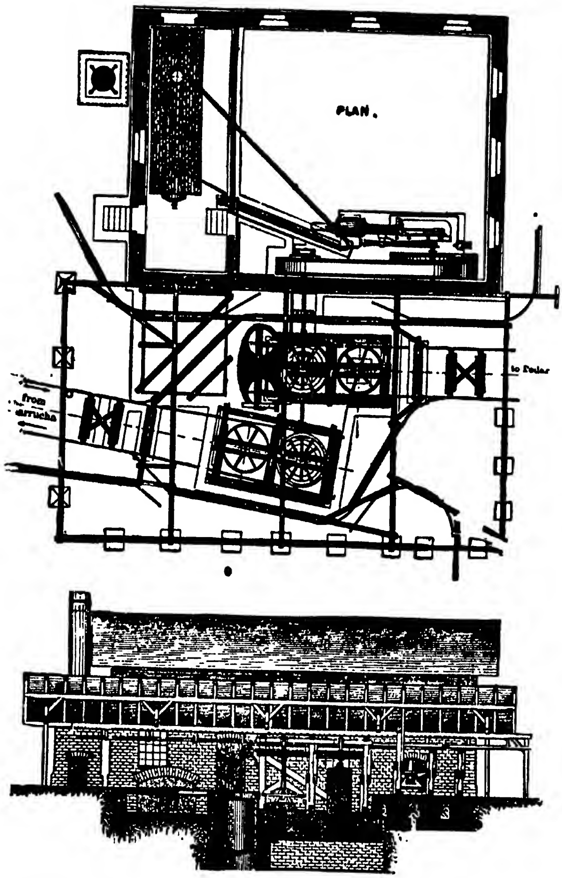
Inclines of from 30 to 40 per cent., it is stated, are easily successfully worked on this plan.

## Installation at Mines in Spain.

A wire rope-way erected between Garrucha and Serena de Bedar in Almeria, south-east of Spain, on the Bleichert-Otto system of fixed carrying rope, was at the time of construction the most important installation of this particular description in existence, and is even now one of great interest. This wire rope-way was constructed for transporting iron ore from the mines at Serena de Bedar to the Mediterranean coast at Garrucha, the total length being 9½ miles.

The line is divided into four sections, the first two of which are 1·40 and 3·29 miles long respectively, and are worked by means of an engine of 30 horse-power; the two second sections are 3·29 and 2·8 miles long respectively, and are driven by an engine of 70 horse-power.

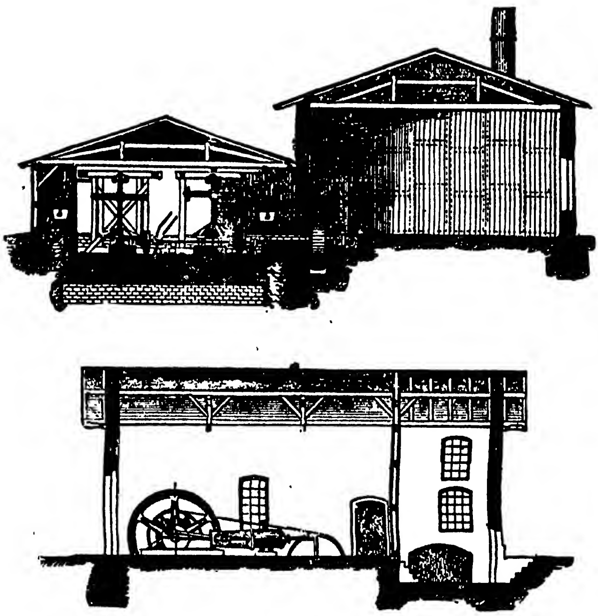
The carrying ropes are firmly anchored at the terminal stations to large blocks of masonry, and are maintained taut by means of tension weights provided at the angle stations, as shown in Figs. 115 and 116, which represents the Puerto del Coronel power and




FIGS. 115 and 116.—Installation at Minos in Spain: Power and Angle Station—Plan and Sectional Elevation.

angle station in plan and sectional elevation. The arrangement of the shunt rails of this angle station, together with the hauling engine, are shown in plan and elevation in these figures and in the sectional views, Figs. 117 and 118.

In operation on the arrival of the carrier buckets at an angle station they are automatically disengaged from the hauling rope, switched on to the shunt rails, and run round by hand to the carrying rope on the



Figs. 117 and 118.—Installation at Mines in Spain: Power and Angle Station—Sections.

next section of the line, where they are again attached to the hauling rope and despatched in a new direction.

The driving is effected by belt gearing which transmits the power to two large grooved pulleys 7 feet 3 inches in diameter, lined with leather, around which the hauling rope is coiled several times. Tension weights and pulleys similar to those employed for the carrying ropes are used for keeping the hauling rope taut.

The loading station is at Serena, which is situated at an altitude of 905 feet above the sea-level, and after leaving this station the line crosses a number of deep valleys, one of which is over half a mile wide and 328 feet in depth, and it traverses mountain ridges, the highest of which is 1,174 feet above the sea-level, to the village of Pendar de Bedar, where, at an elevation of 951 feet above the sea-level, the first power station is located.

From the latter place the line deflects to the right, and again passes over several valleys and ridges, with a gradual descent to an angle station 370 feet above the sea-level. It then bears to the left, extending over a more or less hilly country to the second power station near Puerto del Coronel.

From the second power station the line turns to the right, and descends at an easy gradient to the unloading station on the coast, which is located near the town of Garrucha.

The longest span of the line is that near the Villa Reforma, which is 918 feet in width, with a sag of the rope of 65 feet, and on which six loaded and six empty carriers are supported at a time. The next longest spans of the line range from 328 to 750 feet; the average distance between the supports, however, is only about 130 feet.

The steepest gradient, taking into account the sag of the rope, is 1 in $2\frac{1}{2}$, and the tallest standard is 118 feet in height.

The carrying rope for the loaded side is $1\frac{5}{16}$ inch in diameter, and that for the unloaded side 1 inch in diameter. The hauling rope is $\frac{3}{4}$ inch in diameter, and is provided at proper intervals with star knots* to engage with pawl grips.†

The posts or standards employed are of the type which has been previously illustrated.‡ Fig. 119 is a perspective view of a portion of the rope-way showing the arrangement of the line and the carriers coming and going.

Storage bins of an aggregate capacity of 800 tons are provided at the loading station, from which bins the ore is spouted into the carrier buckets or receptacles.

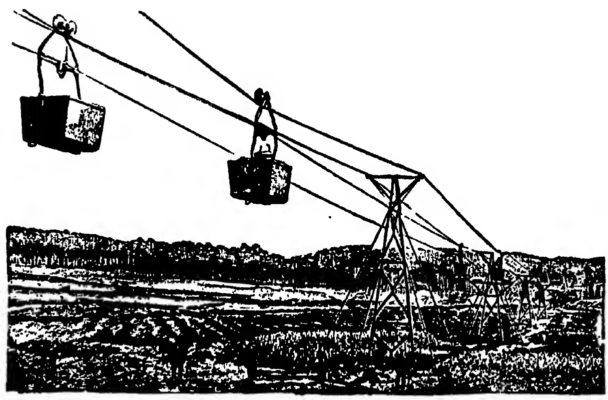


FIG. 119.—Installation at Mines in Spain: Portion of Line.

The unloading station at the coast is 150 feet in length, by 50 feet in width, and is elevated 32 feet above the ground level. It has a storage capacity of from 18,000 to 20,000 tons, so that from four to six vessels can be loaded at a time.

At the various stations sidings are arranged for

* For a description and illustration of these knots, see p 46.

† For a description and illustration of these pawl grips, see pp. 50-52.

‡ See pp. 14, 15, Figs. 1 and 2.

stocking empty carriers from the different sections of the line.

The stations are all connected together by telephone, and a system of electric signalling is used. The engine and boiler houses are solidly built, and are large enough to be used as repairing shops.

The guaranteed capacity of this line is 400 tons per working day of ten hours. With, however, a travelling rate of 300 feet per minute, or about 3½ miles an hour, and with two carriers having buckets of 7 cwt. capacity each arriving per minute, or say 1,200 buckets per day of ten hours, the actual quantity carried by this line in a working day of ten hours would be 420 tons, making its capacity 4,095 ton-miles.

Owing to a large demand for Bedar ore, the line has been worked in two shifts of eight hours, and no less than 900 tons per day have been transported to the coast.

The complete cost of the line is said to have been £26,000, and it was surveyed, constructed, and ready for work within ten months, the constructor of the line, J. Pohlig, of Cologne, contracting to work and keep the rope-way in repair for a number of years at the rate of 1 shilling and 2·5 pence per ton of material carried, this price to cover all the costs of labour, maintenance, and repairs.*

## Installation at Furnaces in Belgium.

A very full description of an installation of the Beer arrangement of wire rope-way on the fixed carrying-rope principle, at the Seraing furnaces of the

* E. H. Davies' "Machinery for Metalliferous Mines" (London: Crosby Lockwood & Son), where (at p. 514) Mr. Davies acknowledges his indebtedness to Commans & Co., of London, the English representatives of the makers, for some of the information supplied. See also British Patent, Otto, No. 7,507, 1887.

Espérance-Longdoz Company, is given in the *Revue Universelle des Mines*,* from which the following particulars are abridged.

The starting point of the line is situated 11 feet 6 inches above the ground level, and the point of delivery is at a height of 160 feet above the starting point.

The carrying rope for the loaded carriers is $1\frac{1}{4}$ inch in diameter, and is composed of nineteen wires, each wire $\frac{1}{4}$ inch in diameter, and arranged one in the centre, six intermediate, and twelve on the exterior. The weight of this rope is $21\frac{3}{4}$ lbs. per fathom, and its theoretical breaking strain 37 tons, the actual breaking strain being, however, appreciably less. It is strained and kept taut in use by a counterpoise of 5 tons 18 cwt.

The carrying rope for the empty carriers is $1\frac{1}{32}$ inch in diameter, and is also composed of nineteen similarly arranged wires to those of the above rope, but each of which wires is only $\frac{3}{16}$ inch full in diameter. This rope weighs but $12\frac{1}{2}$ lbs. per fathom, and its theoretical breaking strain is 23 tons. The counterpoise for straining the empty line is 3 tons 18 cwt.

The hauling rope is $\frac{11}{16}$ inch in diameter, and is composed of a hemp core surrounded by six strands each composed of twelve wires of $\frac{1}{16}$ inch in diameter. It weighs $4\frac{1}{2}$ lbs. per fathom, and has a theoretical breaking strain of 14 tons 18 cwt. The counterpoise for keeping the hauling rope taut weighs 1 ton 19 cwt.

The joints of the carrying ropes are made in two ways. The one by inserting each end into a slightly conical sleeve, somewhat separating the wires, and brazing them to the sleeve with a special solder. The

* "On the Beer System of Wire Rope-Ways," by Charles Raoult, Engineer to the Beer Engineering and Foundry Company, *Revue Universelle des Mines*, 3rd series, vol. iii., 1888, p. 49.

larger or adjacent ends of each pair of these sleeves are tapped with a right and left handed thread respectively, and they are coupled together by means of a right and left handed screw-threaded plug.

The other method consists of separating and wedging the wires into the sleeve instead of soldering. This wedging is effected first by three curved wedges forming conjointly a feather-edged tube or ferrule between the outer and intermediate layers of wires, and next by a smaller solid conical ferrule between the intermediate layer and the central wire, which last wedge piece is screwed at the end and secured by a nut.

A series of tests to which this latter coupling was subjected showed that, although a load of 30·1 tons ruptured all the wires, none of them were drawn out of the sleeve, but all were broken externally, and the joints themselves remained uninjured.

The hauling rope is endless, the two extremities being spliced together, and, in the case of lines where the gradients are slight, the carrier skips or buckets may be attached to it at any point by a simple friction clip easily engaged and disengaged. In the installation under consideration, however, where the gradients are of some severity, carrier collars or knots are fixed on the hauling rope to engage with locking grips on the carrier frames or hangers, which grips are automatically released by coming in contact with a fixed tripper bar or rail at each end of their travel. The carrier collars employed are formed in halves dovetailed together so that they can be slipped on anywhere on the hauling rope, and secured with a small rivet with countersunk heads, by which it is claimed to avoid the injurious effect of solder on the rope, and the necessity of cutting and splicing the latter at each point where a collar has to be fixed, as is necessary when solid thimbles or carrier collars are used. These carrier collars are $1\frac{1}{4}$ inches in external diameter, and $1\frac{3}{4}$ inches in length, and they are fixed on the rope at intervals of 228 feet apart, and when loaded with a weight of 2 tons, and tested by repeated blows of a hammer, no sensible displacement of one of the carrier collars was found to have been effected.

It has been found in practical working desirable to change the position of the carrier collars from time to time so as to equalise the wear on the rope.

The hauling rope is driven by a 9 horse-power vertical engine placed under the platform at the loading or starting station. The crank shaft carries a pinion 8 inches in diameter, and making 120 revolutions per minute, which pinion meshes with a spur wheel 7 feet 6 inches in diameter, keyed on the driving drum shaft, and the driving drum or pulley has two grooves lagged with wood. The hauling rope is passed twice round the driving drum or pulley, and once round a single grooved idle pulley placed above the latter in the same vertical plane, and it is then led away horizontally over two guide pulleys. The return pulley at the discharging station is movably mounted and weighted to keep the rope taut, the counterbalance being, as before mentioned, 1 ton 19 cwt.

At each station a fixed rail is provided on to which the carriers can be shunted, so as to be passed, in the one case, round the return pulley, and in the other round the receiving hopper, for charging. Movable switches are also provided at the starting station to admit of the carriers being removed for repairs, &c.

The travelling speed of the carriers is about $2\frac{1}{4}$ miles per hour.

A fact which has been specially noticed during the working of this line is that the hauling rope constantly revolves on its own axis, and always in the same direction.

The discharging station consists of a platform 66 feet high, carried on a light but very substantial framing steadied by guy ropes.

Three intermediate supports or standards are provided, which consist of wrought-iron lattice posts bolted to masonry foundations, the highest being 72 feet. Each standard is provided with two crossbars for supporting the carrying and hauling ropes, which are placed one above the other in the same vertical plane. The hauling rope is simply carried on grooved pulleys, but the plan adopted for supporting the carrying ropes is a more complicated arrangement, as by reason of the variations of temperature, and of changes in the positions of the loaded carriers, they are found to have an endwise movement to and fro of 10 inches or more. If the creeping movement of the two carrying ropes be in the same direction, it is found to tend to overturn the supporting posts or standards, and if in opposite directions, to twist them.

When the carrying ropes are arranged to merely slide on their supports, they soon become set fast, no matter how well they may be kept greased; if they are carried on simple pulleys, they soon show signs of wear from want of sufficiently extended bearing surfaces; if mounted on blocks or carriages carried on small wheels, the blocks or carriages are found to work themselves to the one or other end of their track or path, and to stick there. To overcome these objections the carrying ropes are, in the Beer system, supported on properly formed blocks mounted on pendulum rods having free endwise motion, but prevented from oscillating sideways by quadrant-shaped guides.

During work a quarter turn over is given to the carrying ropes from time to time, so that all sides of the ropes may be equally worn.

The working staff on this line consists of five persons—an engine and machinery attendant, a filler, and a hooker-on at the starting point, a boy to tip the carrier buckets or skips, and a hooker-on at the delivery point.

The capacity of the line is 130 tons of material transported to a distance of 900 feet per working day of ten hours.

The installation is stated to effect a saving of 66 per cent. as compared with the system previously employed.

## Installation at a Saw Mills in Scotland.

A wire rope-way on the Carrington double fixed carrying-rope system, in which one carrier on each rope is arranged to travel in an opposite direction, and is controlled by an endless hauling rope, is illustrated in Figs. 120 and 121. The line, designed and constructed by Bullivant & Co. Ltd., is used for carrying lengths of sawn timber from a saw mills situated in Farley Forest, Beauly, N.B., to a siding on the Highland Railway. Fig. 120 is a view along the line, the standard in the foreground showing very clearly the method of construction adopted. Fig. 121 is a view of the upper terminal at the saw mills, showing one of the carriers loaded and about to start on its journey to the discharging station.

The length of the line is 1 mile, and the upper or loading station is 540 feet above the discharging station. The rope-way is operated principally by gravity assisted by a small steam engine, and it has

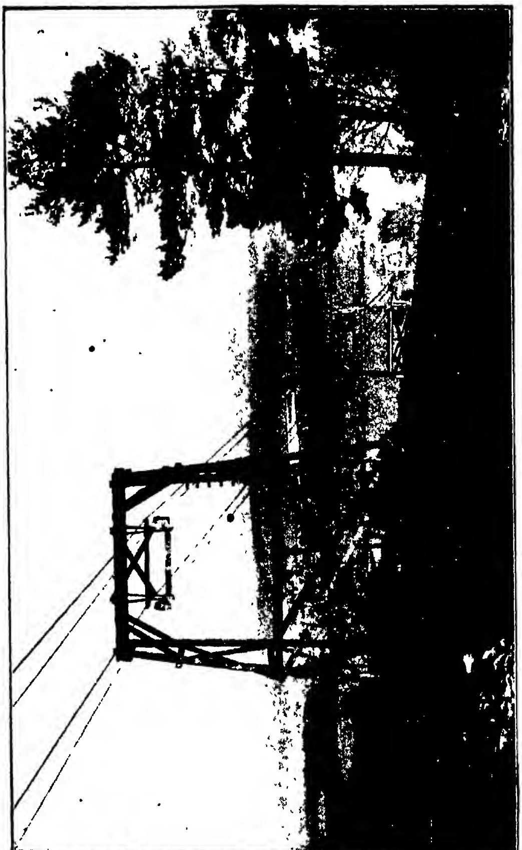


Fig. 120.—Installation at a Saw Mills in Scotland: View along the Line.

a capacity of 40 tons per day, the weight of the individual loads being 1 ton, and consisting of 9-feet and 12-feet lengths of sawn timber.

The terminals at the loading and discharging stations are constructed mainly of sawn timber, the standards—as will be seen from the illustration, Fig.

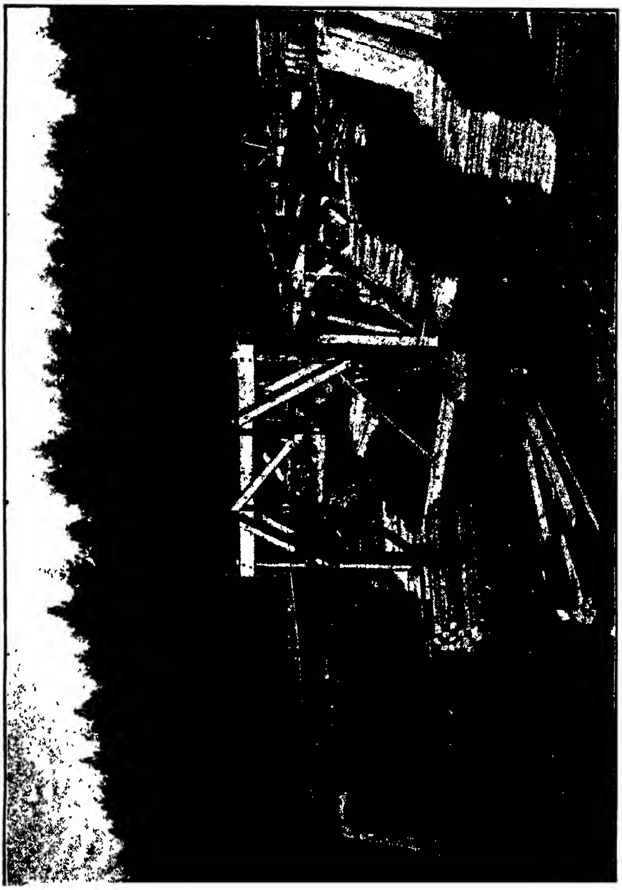


FIG. 121.—Installation at a Saw Mills in Scotland: Upper or Loading Terminal.

120—being of the same material, and of the four-legged pattern, and ladders at the sides are provided for affording access to the upper parts.

## Installation at Blast Furnaces in Hungary.

An installation on the Obach fixed-rope system of wire rope-way was constructed a number of years back in connection with the blast furnaces at Vajdahünyad, Hungary, which is known as the great Transylvanian wire rope-way,* and was at the time of construction about the largest example of this kind of traction in existence.

Obach uses two fixed carrying ropes, and an endless hauling rope passing over horizontal guide pulleys at each end, one of which serves as a strainer, and the other of which is driven by a steam or other motor.

The total length of the line in question is 100,203·21 feet, or nearly 19 miles, and the total fall 2,926·503 feet. The rope-way crosses sixty hill summits and sixty-two valleys, twenty-eight of the spans varying from 656·16 feet to 1,571·52 feet in width, the line being in the latter case 810·36 feet above the bottom of the valley. Gradients of 1 in 1½ exist in many places. The line is divided into numerous sections.

The carrier receptacles for the charcoal are of a capacity of about 17⅔ cubic feet, each carrying a load of 540 lbs., and they are coupled to the hauling rope so that they can be detached automatically at a station, and run on rails to the next section, and so on, the carrier receptacles being empty on the return journey.

The carrier receptacles for the ore have a capacity of 750 lbs. each, and are provided with tipping gear, enabling them to be unloaded by one man; when empty they return continuously by the opposite line.

* *Oesterreichischen Zeitschrift für Berg- und Hüttenwesens*, vol. xxxii., 1884, p. 723; *Annales des Mines*, vol. ix., 1885, p. 185; and *Minutes of Proceedings of the Institution of Civil Engineers*, vol. lxxx., pp. 380-382, and vol. lxxxvi., pp. 415-417.

The number of loaded carriers transported is one hundred per hour, two-thirds of which bring ore and one-third charcoal.

In the lower section of the line the gradients are with the load, so that this portion of the line is self-acting when fully loaded, requiring even the use of brakes; when, however, the down load is insufficient, or return freight has to be carried, supplementary steam power has to be employed.

The highest standard used on the line is 88·8 feet in height, and is located at a point where a crossing of 2,145·12 feet is divided into two spans of 1,082·4 feet and 1,062·72 feet. It consists of a double frame with a saddle for supporting the carrying rope to prevent injury from bending, and a system of rollers for the hauling or driving rope to relieve the oblique strain upon the carrier frame or hanger.

As a general rule the standards are constructed of round timber, two types being employed, the one for the heavier section of the ore line having double posts with the line suspended from the cross-pieces above, whilst the other for the lighter sections has single posts with the line overhanging from a **T**-piece. Wherever the standards exceed 49·21 feet in height, they are provided with diagonal wind bracings.

The bearing or carrying ropes are supported upon the standards in cast-iron shoes, having smooth grooves where the pressure is light, and bearing rollers where it is heavy. On slopes the latter are placed on swinging bearings, so as to take the inclination of the line automatically.

The ropes used are of the best class of steel wire, the carrying ropes being of $\frac{17}{25}$ inch in diameter, and the hauling ropes of $\frac{13}{25}$ inch in diameter, on the charcoal line, and of 1 inch diameter and $\frac{18}{25}$ inch diameter respectively on the ore carrying line.

The apparatus for coupling the carriers to the hauling rope grips the stops on the latter from above, closing by a self-acting motion which is so contrived that it cannot be released during the journey either by accident or design, and will pass freely over the guide rollers, thus admitting of very wide spans with rapid changes of slope being traversed with only a minimum amount of constructive difficulty in the way of standards.

The cost of transport on the above line is given as approximately averaging about 1s. 1¾d. and 1s. 2¼d. per ton per mile for ironstone and charcoal respectively, including a sufficient allowance for depreciation and interest on capital. The cost of the complete installation was £46,000.

## Installations at a Cement Works in France.

A wire rope-way* used for transporting from the top of Mount Jalla, which rises above the town of Grenoble, in France, the material for the manufacture of the Porte de France cements, affords another interesting example of this mode of transport.*

The line consists of a single span of 1,970 feet in length, and the vertical distance is 1,017 feet.

Two fixed steel wire ropes or cables are provided, both having diameters of 1·77, or about 1¾ inches. One of these ropes is anchored in the rock at the top, and kept stretched by being wound round a drum at the bottom, and on this line a carrier adapted to transport about a ton load of stone is run. The

* For full description of this installation see *Le Génie Civil*, vol. vii., 1885, p. 369; and *Annales des Ponts et Chaussées*, 1877, p. 390.

second rope or cable supports another carrier which is connected to the first carrier by an endless cable of 0·709 inch in diameter, passing round a brake pulley at the summit, and round a second pulley at the base, which latter is secured to a loaded frame running on four wheels up and down an inclined plane, so as to maintain the requisite tension of the cable constant, and regulate the motion of the carriers. It will be seen that by reason of this arrangement the descent of the loaded carriers is utilised to draw up the empty carriers.

The ascent of a carrier occupies about one and a half minute, the whole operation, including loading and emptying, being performed in the remarkably short time of three minutes, the travelling speed being about 20 feet per second, or nearly 14 miles an hour. The carrier receptacles have a capacity of about 32 cubic feet, the boxes being slung below hangers or frames, each having two grooved pulleys running upon one of the fixed ropes.

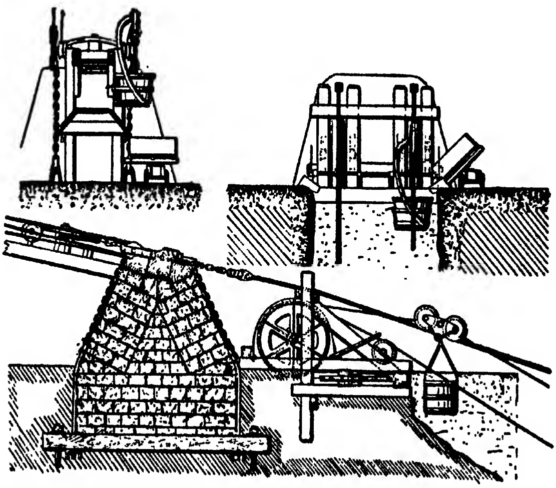
This wire rope-way was erected at a cost of £620, and is capable of delivering a supply of from 120 to 150 tons of stone per day of twelve hours to the cement works.

A second similar line, erected a year subsequently to the above, supplies stone to the works from a lower quarry, the latter being, however, only 1,000 feet in length.

At the time of erection the single span of the first rope or cable way, which it will be seen is one of nearly 2,000 feet, was remarkable for its length, being in fact supposed to have been the longest then in existence, although at the present time ones of considerably more than double that length can, as has been already mentioned, be easily negotiated.

## Installation at Lead Mines in France.

An example of an installation* on the Carrington double fixed-rope system, interesting on account of the physical features of the ground to be crossed, is a line erected at the Sentein lead mines near St Girons, in the Pyrenees, France, the details of which are shown in Figs. 122, 123, and 124.



FIGS. 122, 123, and 124.—Installation at a Lead Mine in France: Details of Construction.

The inclines on this rope-way are five in number, the lower terminal of one incline joining the upper terminal of the next incline, and so on, suitable points for these terminals being found at the ends or sides of the spurs of the mountain near the line of the wire rope-way.

The following are the lengths and inclinations of

* See *Minutes of Proceedings of the Institute of Civil Engineers*, vol. xlv., pp. 299-309.

the sections:—No. 1, 813 feet in length, with a fall of 99 feet; No. 2, 2,025 feet in length, with a fall of 690 feet; No. 3, 1,230 feet in length, with a fall of 270 feet; No. 4, 2,934 feet in length, with a fall of 1,290 feet; and No. 5, 1,530 feet in length, with a fall of 390 feet.

The No. 1 incline commences at the mouth of the mine, and forms a junction with No. 2 incline at the edge of a cliff about 300 feet high. No. 2 incline crosses a span of 2,025 feet, and joins No. 3 incline at an elevated point on the steep side of the mountain, a small platform being cut out of the latter for that purpose. No. 3 incline stretches across a deep ravine, and effects a junction with No. 4 incline at the extreme end of a spur of the mountain, a flat space being cut off its pointed top, the sides shelving at an angle of 60° with the horizon. No. 4 incline spans a valley 2,934 feet across, and about 1,500 feet deep, and joins No. 5 incline on the side of the mountain. No. 5 incline stretches thence down into the bottom of the valley, terminating close to the cart road to the works. These inclines are identical in principle, differing only in length and gradient.

The lines consist of two crucible-steel fixed carrying ropes of 75 tons breaking strain, anchored at the upper end, and stretched across the space between the terminals, the lower end being held by a pair of blocks fitted with flexible steel-wire rope, by which the fixed ropes are tightened. At each end they pass over a massive masonry saddle, as shown in the vertical sectional view, Fig. 124.

Fitting the tightening blocks with a long flexible rope allows of their being slackened out enough to lie on the ground for the purpose of repairs; the strain put on them is about 12 tons.

The carrier receptacles for the ore are made of steel plates; they measure about 2 feet 9 inches long by 2 feet wide and 2 feet deep, and are intended to carry from 14 to 15 cwt. each; they are each hung on the fixed carrying ropes by means of a curved frame or hanger, fitting into a pair of plates carrying between them two deeply-grooved steel wheels 15 inches in diameter on the treads, which fit the fixed carrying rope. These plates also carry a small safety wheel located under the rope, which wheel is so placed as normally not to touch it, but which will prevent the larger grooved wheels being jerked off the carrying rope.

The carrier receptacles are arranged to empty by the bottoms, the latter falling on the turning of a handle fixed to their sides. A carrier is placed on each of the two parallel fixed carrying ropes, and the two carriers are connected by a light wire rope of 7 tons breaking strain, of such a length that when one carrier is at the upper end of one rope, the other will be at the lower end of the second rope. For example, if one carrier be charged with 14 cwt. of ore while standing on the upper end of one of the fixed carrying ropes, it will run down this rope by gravity, dragging up the empty carrier on the second fixed carrying rope by means of the light hauling or driving rope, the speed being governed by a powerful brake located at the end of the incline.

This brake gear, round which the hauling or driving rope is passed, consists of two vertical drums or wheels, 5 feet in diameter, having grooved wooden rims, placed 5 feet apart, each wheel being fitted with a powerful brake. The hauling rope is passed over the first of these vertical drums or wheels, next round a wheel 5 feet in diameter, placed horizontally in front at the feet of the two vertical wheels, and then round the second vertical drum or wheel. This plan is said to produce an adhesion to the two vertical brake drums or wheels equal to rather more than that derived from two half turns on these wheels. A second hauling rope of the same size connects the carriers by passing round a horizontal drum at the lower end of the incline, and the latter is arranged to be drawn back by means of a screw, to regulate the tension on both the hauling ropes.

Owing to the great elevation at which most of the stations are situated, the work of erection was difficult and expensive. The conveyance of the ropes up the mountain was especially so; the total weight was about 30 tons, and the ropes had to be divided into coils weighing 20 cwt. each, as it was found impossible to take up a heavier weight by cart, and even then in conveying these 20 cwt. or 1 ton coils to the upper parts of the line five horses were required to each, and only one coil per day could be delivered.

The transport of the machinery, carriers, &c., was equally, if not more, difficult and expensive.

In building the masonry saddles, owing to the frequent occurrence of frost at night, even during the earlier part of the autumn, it was found to be impossible to place reliance on the mortar used, and these masonry saddles were therefore strengthened with massive timber trestles, fixed round the stonework, which assisted them in taking part of the vertical strain. By arranging the junctions of the adjoining sections the strain of one is made to balance to a considerable extent that of the other, and by the anchorage of the fixed ropes of each of these sections to the same foundation beam, which was placed under the saddles, and also strongly bolted down to the rock, the weight of the masonry is made to act to materially increase their security.

The inclines joining one another at a horizontal angle, and on very confined spaces of ground, rendered it necessary to arrange for transferring the contents of the carrier receptacles from one section to the next by means of small tip waggons running on a short and slightly inclined rail, between the point where the loaded carrier stops to discharge, to that where the empty carrier stands at the top of the adjoining section. These waggons can easily be run with the assistance of one man, who, when he has discharged the contents of a waggon into the empty carrier, pushes it back into its place, ready to receive the contents of the next loaded carrier. A similar arrangement is, of course, provided on both sides of each station.

Had it been possible to obtain better and more spacious sites for the stations, the usual arrangement of placing the anchorages so that one carrier could tip its contents direct into the empty carrier on the adjoining section would have been adopted, and the lower ends of the fixed carrying ropes could then have been anchored by means of weights.

The carriers are allowed to run by gravity at the comparatively high speed of about 25 miles per hour, and when the brakesmen have become accustomed to their duties, it is found that they can regulate this speed to a nicety, and bring the carriers to a standstill at the proper points with perfect smoothness and accuracy.

The quantity of ore which can be transported by these inclines depends, of course, on what can be got over the longest section; and while, owing to the exigencies of the route, it was necessary that the sections should vary greatly in length, it was attempted to equalise their carrying capabilities by making the longer sections steeper than the shorter ones, thus enabling the carriers to be run on the former at a higher speed, a plan which is found to be to some extent successful.

In putting up a series of inclines, such as those described, it is most advisable to equalise, as far as possible, the carrying powers of each section.

The amount of ore which has been regularly brought down by this system has been from 70 to 80 tons per day, but if sufficient mineral were provided, 100 tons per day could be transported. A trial with the 2,025 feet (No. 2) section, before the men had become thoroughly acquainted with its working, proved that 12 tons per hour could be taken down.

The cost of carriage is about 2s. per ton, exclusive of maintenance, which may be taken at 1s. 2d. per ton, or making a total cost of 3s. 2d. per ton.

The maintenance charge on this installation is exceptionally heavy, owing to the very exposed situation, and to the fact that for two months of the winter at least no work can be done, the plant meanwhile being exposed to the full deteriorating action of the weather.

This wire rope-way admits of the transport of mineral being carried on without stoppage while the roads are buried in snow to a depth of several feet. Thus the works can be supplied with ore for a much longer portion of the year than would be possible by any other means of transport.

## Installation at a Gas Works in London.

An example of a short line of single fixed-wire rope-way is shown in Fig. 125. This rope-way was erected some years ago at the Nine Elms Works of the London Gaslight Company, and after working successfully for some time it had to be removed to make room for building operations. The rope-way was used for the transportation of about 25 tons of coal per hour across a dock, a distance of 450 feet between the supports.

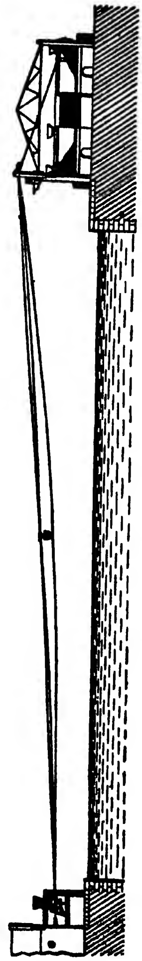


Fig. 125.—Installation at a Gas Works in London: Sectional View.

The load was taken up a nominal incline of 1 in 19, and conveyed in a carrier receptacle or bucket which held about 17 cwt. The carrier was drawn along the fixed carrying rope by a small crucible-steel hauling rope of $4\frac{1}{2}$ tons breaking strain driven by an engine of 6 horse-power, at a speed of 5 miles an hour, and the contents were tipped into a hopper; after which the carrier was run back again at a speed of 10 miles an hour, and brought under a hopper from which it was loaded.

The single carrying rope used was one of crucible-steel wire, of 40 tons breaking strain, which was stretched across the dock. The upper end was fixed to a timber framing, attached to the retort house at about 45 feet from the ground, the attachment being tied back by another wire rope, exactly on the same line as that over the dock, the end of which was anchored to the opposite wall of the house near the ground. The lower end of the rope across the dock was held by a weight of 4 tons acting on the double purchase system, which thus exerted a strain of about 8 tons, and the strain on the rope being thus kept constant whether a loaded carrier was running upon it or not.

The carrier receptacle was of iron, and was suspended by means of a curved hanger or frame fitting into a running head or traveller which rested on the fixed carrying rope. This running head or traveller was formed of two strong iron plates carrying between them, one near each end, two deeply-grooved cast-iron wheels, about 9 inches in diameter on the treads, and made to fit the fixed carrying rope, and the edges of their rims being turned true so as to also run on the rail under the loading hopper. The wheels were mounted on steel pins fitted between the wrought-iron plates, through which latter, between the wheels, the curved hanger or frame attached to the carrier receptacle also passed. The bottom of the carrier receptacle could be let fall by a simple arrangement of lever and catch.

At the lower or loading end the carrier ran off the rope on to a rail, where it stood with the receptacle under the door of a hopper. When loaded it was drawn across to the discharging end, hanging on the fixed rope by means of the running head or traveller, at a speed of 5 miles per hour, and as already mentioned up a nominal incline of 1 in 19, but which, owing to the bend or sag in the rope, was often in reality as much as 1 in 10. The hauling rope was passed round a horizontal drum mounted at the upper end of the line in the wooden frame which carried the attachment of the fixed carrying rope, and was put in motion by a simple arrangement of driving gear consisting of a horizontal wood-rimmed drum driven by bevel gearing, so that it could be moved at 5 miles per hour in the forward and at 10 miles per hour in the backward direction. This driving drum had two parallel grooves, and by means of a smaller drum placed at one side of it the hauling rope was made to pass twice round certain portions of its circumference, and thus increase its driving power, as well as admitting of taking up any small amount of stretch in the hauling or driving rope. The driving gear was mounted on a substantial wooden frame, and alongside it was located the small engine of 6 horse-power which provided the necessary motive force. It was found in practice that 30 lbs. of steam (8 horse-power actual) drove the engine at the required speed.

The labour employed when working full capacity comprised one driver, one trimmer, and one man at the discharging end.

The routine of working was conducted as follows:—The carrier having arrived under the loading hopper, the driver pulled up the door, and the receptacle or bucket was filled, the trimmer levelling with a shovel the coal as it fell. The driver then shutting the hopper door, engaged the forward motion of the driving gear, and the loaded carrier was drawn across to the discharging hopper. The driver then put on the brake and stopped the motion of the carrier, and on receiving the signal from the man at the other end that he had emptied the carrier receptacle or bucket and replaced the bottom, put the backward gear in motion so as to draw the empty carrier back to the loading hopper at a speed of 10 miles an hour. In regular working the whole of the operations described occupied two minutes, so that thirty runs were made per hour. Including filling and emptying, however, it is said to have been found practicable to make thirty-five runs an hour, and even ten runs in fifteen minutes.

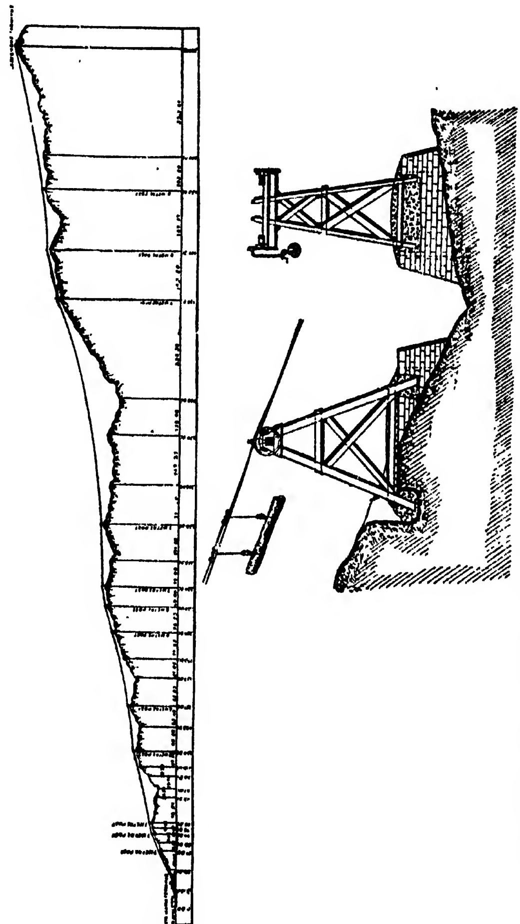
The cost of labour was found to be 0·88 penny per ton; the renewal of ropes, wheels, and general maintenance 0·4 penny, of which the ropes absorbed 0·26 penny. In all, excepting fuel, the cost of loading, transporting up 450 feet of an incline of 1 in 10 to 1 in 19, and discharging, was 1·28 penny per ton. The prime cost of the machinery, ropes, and steam engine was £340.

## Installation at a Saw Mills in Italy.

Figs. 126 and 127 illustrate a double fixed wire rope-way on Carrington's system erected at Santa Maria di Capua, Monte Penna, Caserta, Italy. This line is about 2 miles in length, with an average incline of about 1 in 5. It is used to carry timber and charcoal from a forest to the saw mills of the company, and passes over a very mountainous country, as will be seen from the sectional view.

The down or heavy load line is a steel wire rope 3¾ inches in circumference, or about 1·2 inch in diameter, with a breaking strain of 42 tons. The up or light load line is a steel rope 3 inches in circumference, or about ·96 inch in diameter, with a breaking strain of 25 tons, and the hauling rope is a plough steel rope 1½ inches in circumference, or about ·48 inch in diameter, with a breaking strain of from 8 to 9 tons.

The section of the line shown in Fig. 126 is 8,562 feet in length, and in that distance the ropes are supported at twelve points on posts or standards, the unsupported spans varying in length from 93 feet to 2,229 feet. The posts or standards shown in side and front elevation in Fig. 127 are 23 feet in height, a carrier being also shown to illustrate the mode of support.



Figs. 126 and 127.—Installation at a Saw Mills in Italy: Section and Details of Standards.

The fixed carrying ropes are kept at the required tension by box weights suspended at the upper terminus (Carignone) to a strong wooden framework, and at the lower terminus (Santa Maria) in wells or pits especially excavated for the purpose.

The hauling rope passes over a horizontal drum with brake gear attached, at the upper terminal station, and round vertical driving and brake drum gear, guide wheels, and a horizontal slide drum, &c., at the lower terminal station. The horizontal slide drum regulates the tension of the hauling rope to the required tractive force.

The line is driven at a speed of 4 miles per hour, the motive power being derived from a turbine, and it can be set in motion or stopped by the person in charge of the Santa Maria terminal station, from which communication is carried on with the Carignone terminal by an electric bell telegraph.

The loaded carriers are placed on the line 1,425 feet apart, at which distance rings are spliced into the hauling rope, through which rings shackles are passed to connect them to ear-pieces on the carrier heads. There are six carriers on the down line, and six on the up line, one of which on each line is arranged to arrive at the stations simultaneously. On arrival they are disconnected, and the hauling rope is moved on until the rings are in position to attach on the opposite side. Here another carrier is connected, and the line is again set in motion.

The carriers and slings for the timber weigh 5 cwt. each, and the loads vary from 6 cwt. to 25 cwt., according to the size of the logs of timber, &c., the usual loads, however, being about 12 cwt. each, single logs of 25 cwt. being only occasionally brought down. All necessaries for the workmen in the forest are sent up on the light load line in weights up to 1½ cwt.

This rope-way is constructed in a very substantial manner, and most of the timber for the stations, posts,

FIG. 128.—Installation in the Italian Alps: Lower Terminal and View of Line.

&c., have been injected with a solution of sulphate of copper to retard decay.

The total cost of the line was £4,000, including the construction of a short inclined railway at the Santa Maria terminal, telegraph, terminal arrangements, &c. It is capable of conveying eight loads per hour, or per day of ten hours as many as two hundred logs of timber, 10 feet long by 15 inches in diameter, or 320 sacks holding 25 tons of charcoal.

The cost of working the line is about £4 a day, nearly 50 per cent. of which sum is absorbed for wear and tear of the ropes and machinery.

The following are figures showing two years' working of this wire rope-way:—

| | 1887. | 1888. |
|---|---|---|
| Total number of loads carried | 11,545 | 8,959 |
| Number of logs carried | 11,127 | 10,206 |
| Number of sacks of charcoal | 22,659 | 18,589 |
| Wages of tramway staff per load | Lira * 0·70 | Lira 1·38 |
| Stores, new ropes, repairs, &c., per load | 0·30 | — |
| Average number of loads per working hour | 8·6 | 5·0 |

*Note.*—The 1888 working season, owing to bad weather, only began in May and finished in November, a period of only six months' duration.

## Installation in the Italian Alps.

A wire rope-way on Carrington's fixed-rope system, constructed by Bullivant & Co. Ltd., and erected in the Italian Alps at Pinerolo, Piedmont, is illustrated in Fig. 128, which shows the lower terminal and the line extending away to the upper terminal in the far distance on the mountain side. In this type of line (a general description of which has been previously given) it will be remembered that two parallel fixed

* Lira equals 9½d.

carrying ropes are used, and a carrier is mounted on each rope, which carriers are so connected that when one of them is descending one rope the other one will be ascending the other rope, and *vice versâ.*

The view illustrating this installation is a reproduction from a photograph of the line taken when at work.

## Installation at Fortifications, Gibraltar.

Fig. 129 is a section, showing an interesting example of wire rope-way for both passengers and

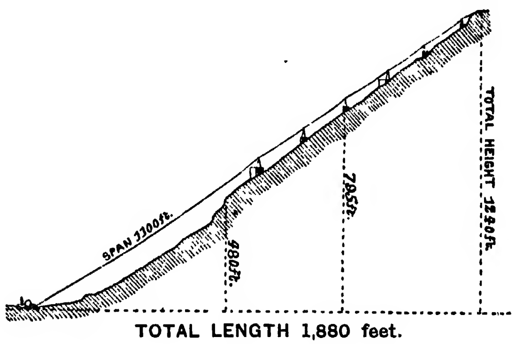



FIG. 129.—Installation at Fortifications, Gibraltar: Section.

goods working up a very steep incline, constructed at Gibraltar for the War Office by Bullivant & Co. Ltd. The line, which is of a similar type to that which has been just described, is used for the transport of stores and goods of all kinds to various stations situated at different levels on the rock, and also for the conveyance of workmen.

The length of the line on the incline is 2,200 feet, on the level 1,880 feet, the vertical height is 1,240 feet, the average incline is 1 in 1·6, and the longest span is one of 1,100 feet.

The loads carried on this wire rope-way are of 10 cwt. or more, and the arrangement is such that one load travels up the incline whilst the corresponding load travels down.

## Installation at Water Works, Cape Town.

Fig. 130 shows a section of another installation, a portion of which is also on a very steep incline. This rope-way is on the Carrington single fixed-rope system, and it was constructed up the Table Mountain near Cape Town by Bullivant & Co. Ltd., for the corpora-

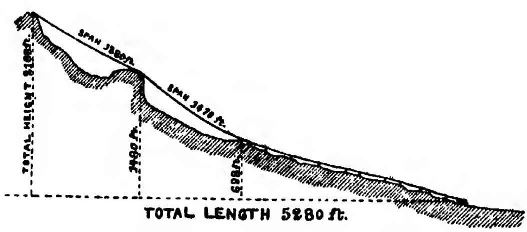



FIG. 130.—Installation at Water Works in South Africa: Section.

tion of that city, and used for the purpose of carrying the materials and machinery required for the construction of their new reservoirs, which are situated on the mountain at a height of 2,168 feet above the city. The nature of the country to be passed over opposed great difficulties to the successful erection of a wire rope-way, which difficulties cannot be fully realised from the section.

The line, as already mentioned, is on Carrington's single fixed-rope principle, which has been already generally described in a previous chapter. The single carrier is run on the carrying rope at a speed of about 8 miles an hour by the endless hauling rope, which is attached to it, and which passes round suitable gears at each terminal.

The motive power, consisting of a steam engine, the driving gear, and a powerful brake arrangement, are located at the lower terminal or starting point, Tightening or straining gear is provided at the upper terminal.

The length of the line on the level is 5,280 feet, or exactly 1 mile, and the average incline is 1 in 2·5, the two longest spans are one of 1,470 feet and one of 1,380 feet.

Loads of 15 cwt. and upwards can be transported with safety on a line of this description.

## Installation as a Pier in South Africa.*

In Fig. 131 is illustrated the sea-staging, with a portion of the rope and the carrier in view thereon, of an installation of wire rope-way, also constructed on the same principle as that at Cape Town, which has just been described.

This wire rope-way, as well as the previous one, and the other installations mentioned on the Carrington system, were constructed and erected by Messrs Bullivant & Co. Ltd. The line is for the purpose of conveying materials from ships lying alongside the staging, to the shore, in a locality in South Africa where the surf is of such a character as not to admit of vessels lying closer to land. The crane for lifting the materials out of the vessels is worked by the motion of the endless hauling rope.

The illustration is a reproduction of a photograph showing the line in actual work.

* For description and illustration of wire rope-ways on the running or endless rope system, arranged as piers, see pp. 116-118.

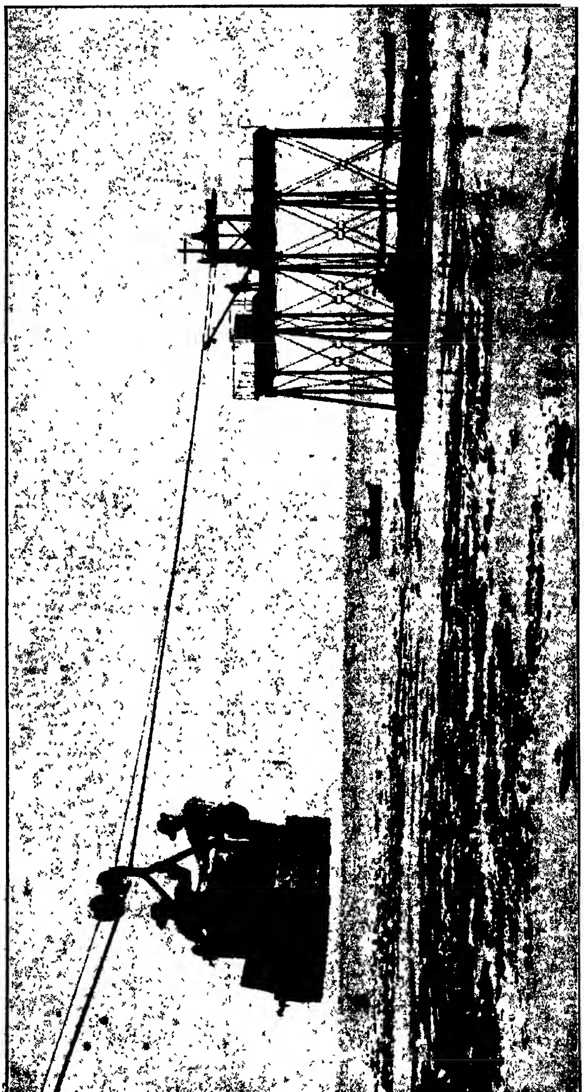


FIG. 131.—Installation as a Pier in South Africa: View of Sea-Staging with a portion of Rope-Way and Carrier thereon.

## Installation for Passenger Traffic at Sugar Factory in Hong Kong.

Fig. 132 is a sectional view, showing a passenger wire rope-way constructed at Hong Kong for conveying the workmen employed at a large sugar usine or factory to and from their quarters in the mountains. The length of the line on the level is 6,300 feet, or about $1\frac{1}{5}$ mile, and the vertical height is 1,090 feet.

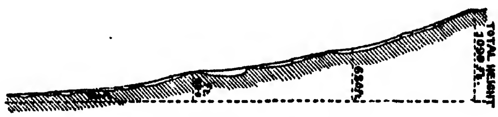



FIG. 132.—Installation at a Sugar Factory in Hong Kong: Section.

The carrier or vehicle is adapted to accommodate six men, and when fully loaded it has a gross weight of about 1 ton.

## Installation at a Mine in Japan.

Fig. 133 is a section showing another example of a fixed wire rope-way working up a steep incline. The line in question, which is located in Japan, serves to transport minerals from a mine or quarry situated at a high elevation to a railway running along the foot of the mountain.

The length of the rope-way is 5,004 feet, the vertical height is 2,490 feet, the average incline is 1 in 2, and the steepest incline is one of 1 in 1·5.

By reason of the sudden change of the incline at an intermediate point, the section presented special obstacles to surmount, and this application represents as difficult a one as could be well met with.

The carrier receptacles or buckets for conveying the minerals contain about 4 cwt. each, and are all

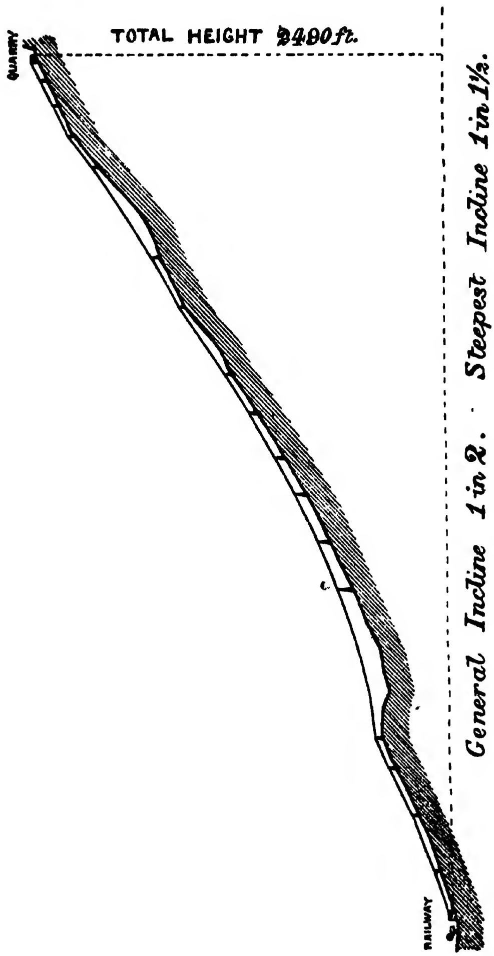



Fig. 133.—Installation at a Mine in Japan: Section.

fitted with automatic clips or grips which are arranged to grip the hauling rope at any point, and release themselves automatically on striking against a wiper or plate fixed in a suitable position at each of the terminals.

A specially designed power absorber deals with the greater proportion of the vast amount of power developed by the descent of the comparatively large loads on such a steep incline, thus rendering it practicable to control the line by means of the ordinary brakes with the utmost facility.

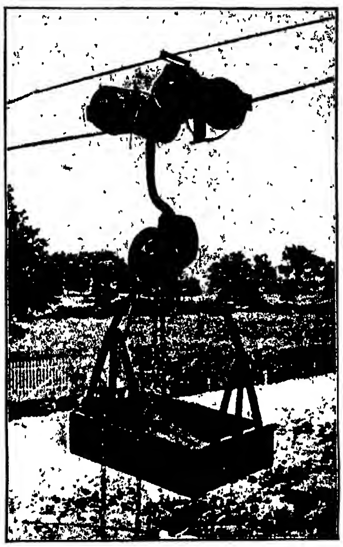


FIG. 134.—Installation on Telpher System: Portion of Line with Truck and Carrier.

## Installations on the Telpher System in Somersetshire and Sussex.

An installation of a wire rope-way on the fixed carrying-rope system, in which electricity is used as the motive power, the arrangement being what is known as telpherage, was erected some twenty years ago at Weston, in Somersetshire, and about the same time an overhead telpher line was also working at Glynde, in Sussex.

As a description of telpherage has been given in a previous chapter entirely devoted to the subject, there is no need here to enter into an account of any of the constructive details.

With the first installation Professor Jenkin experimented very fully for about four months, during which time the fall and rise of insulation resistance were found to be exceedingly sharp, ranging from 2 megohms to 3,000 ohms. The line, which was only 660 feet in length, was tested three times a day by Mr Lineff for Professor Jenkin.

The line working at Glynde was completely in the hands of labourers, who, it is stated, were found quite competent to do the work, and during six months' operation no accident happened except to the armature of the fixed dynamo machine. This line was erected in a brick works, and the materials were carried at a low rate of speed in a continuous succession of carrier receptacles or skips containing from 2 to 3 cwt. each.

It must, however, be observed that these labourers, having presumably received a certain amount of preliminary training or instruction, could not be compared to completely unskilled and unsupervised men, or to the native labour usually employed on such lines in out-of-the-way locations abroad.

## Installations on the Telpher System in America.

The telpher system is peculiarly well adapted for installations on practically level sites, as, for instance, for the transportation of goods or materials from one part of a warehouse, factory, or works to another, over intervening yards or buildings, and for this purpose many aerial wire rope-ways are in successful operation, especially in the U.S.A.

Fig. 134 is a view showing a portion of a telpher line, and Fig. 135 is a view at the works end showing the unloading station of an installation designed and constructed by the Consolidated Telpherage Company

FIG. 135.—Installation on Telpher System: View at Works End of Line.

of New York, at Ampere, N.J., United States, for conveying castings from the brass foundry to the Electric Company's works. This line is on what the inventors call the double unit system, a description and illustrations of which, and also of their single unit system, will be found in a previous chapter. For convenience of loading and unloading, the platform car or carrier is so arranged that it can be raised and lowered by a single speed safety hoist of 500 lbs. capacity. The double unit telpher truck which carries steel pole pieces, and the disposition of the platform and hoist, are illustrated in Fig. 136. Fig. 137 is a view showing the upper portion of one of the posts or standards.

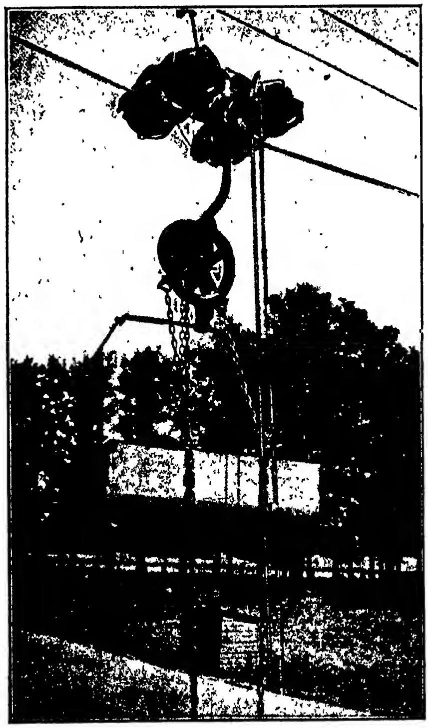


FIG. 136.—Installation on Telpher System: View showing Truck with Carrier and Hoist.

The telpher truck can be started by turning a switch, and within a short distance the speed can be accelerated if required. The castings are placed on the carrier at the foundry as soon as ready, and the circuit being completed, as above mentioned, by manipulating the switch, a start is made towards the factory, slowly at first, then increasing in speed until a curve is approached where the speed is automatically reduced, increasing again until near the termination of the line when an automatic slowing down is again effected, until a final gradual stop takes place either directly over the weighing scales at the receiving clerk's station or at the door of the store room as may be arranged. The telpher truck and carrier can be re-started on the return journey to the foundry with new patterns, &c., and is only the work of a few seconds. As compared with the old method of cartage this system effects a saving that would allow for interest on the outlay and quickly repay the cost of the installation. There is also to be considered the saving in time and labour, increased efficiency of the foundry, and of the works as a whole, and great general convenience, all tending to reduce the general expenses.

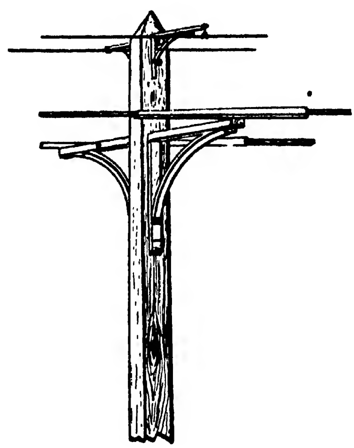


FIG. 137.—Installation on Telpher System: View showing Upper Portion of Standard.

A telpher line for transporting sand from barges to a building a distance of 700 feet comprises two telphers. One of these runs on a track carried on a steel boom projecting over the water from a lofty steel tower at the dock edge, and conveys the sand in buckets to a hopper. The other carries a car charged by the hopper, and runs from the dock over a railway to the upper part of the store. The plant is worked by two men

# CHAPTER VI

WIRE ROPE-WAYS FOR HOISTING AND CONVEYING: INSTALLATIONS FOR HOISTING AND CONVEYING IN AMERICA—INSTALLATIONS FOR HOISTING AND CONVEYING IN AUSTRALIA—WIRE ROPE-WAYS FOR COALING VESSELS AT SEA.

## Wire Rope-Ways for Hoisting and Conveying.

THERE are many special arrangements of wire rope-ways for the above purpose, as may readily be supposed, special circumstances giving rise to many particular designs to meet varying requirements.

For example, to remove earth from trenches during excavation or for open pit mining, a wire rope-way has been designed having separate branch ropes for the guide wheels, and connected with a drum or draught rope, what is usually known as a Turk's head being employed to prevent the buckets from being hoisted too high. The rope is prevented from sagging by a small swivelling traveller.

The following is a brief description * of a special form of wire rope-way in successful use in the United States for both hoisting or raising and conveying loads.

The main carrying rope used has a diameter of 2½ inches, with spans between the suspending towers of 1,000 to 1,500 feet, and weights of from 4 to 8 tons can be raised and dealt with. The main carrying

* For full account of this arrangement, see *Transactions of the American Society of Civil Engineers*, April 1894, p. 397.

rope passes over oak saddles on these towers, and is anchored at each end to the earth.

The carrier runner or carriage consists of two flanged wheels adapted to run upon the carrier rope, and the axles of which are connected together by a frame extending below them. In this frame are mounted two pulleys, over which the hoisting rope passes to the fall-block. The runner or carriage is hauled by an endless rope, attached level with the axles to both the front and back wheels, and returning above the runner or carriage, and passing between two guide pulleys, working in the frame of the latter. At one end this hauling rope passes over guide pulleys in the tower, and is wrapped five or more times round the 54-inch drum of a steam winch which gives it motion. The hoisting drum works alongside the latter, and is of the same size, so that by working the two drums in opposite directions at the same rate, the weight is kept at a constant height and at the same time will be moved horizontally.

To support the hoisting rope a special device is employed consisting of a horn on the back of the main carrier runner or carriage that holds a number of subsidiary carriers which are left (as the carriage moves along the main carrying rope or cable) at suitable distances apart, to support the hoisting rope from the latter. To effect this an auxiliary rope of about $\frac{5}{8}$ inch diameter is suspended above the main cable and held at a constant distance from it at the runner or carriage by passing under a pulley attached to the runner frame. On this rope is a series of buttons equally spaced, and increasing in diameter with the distance from the tower at the working end. Slots in the heads of the subsidiary carriers, corresponding to the diameter of the buttons, cause each one, as the carriage passes along the cable, to be stopped at its proper button.

It will be observed that the load can be hoisted or lowered at any point under the line of the carrying rope, and that horizontal motion can be given to the load at any height to which it may be raised.

This type of wire rope-way can be advantageously employed in open pit mining operations, and other excavations, and is said to be found very efficient in the construction of any works which can be spanned by the main carrying rope.

An arrangement intended for conveying goods between a vessel and a warehouse consists of a jib crane combined with an inclined rope-way. A double jib is hinged to a foundation plate fixed on the quay, and is supported by an inclined wire rope-way passing over a sheave, and connected to a counterweight located within the building. This weight is so adjusted as to be sufficient to raise the jib, which latter is lowered by means of a crab or winch, and operating blocks and tackle, connected to it and to the foundation plate, the rope being clamped above the counterweight when the desired position is obtained. Upon this rope-way is mounted a wheeled carrier, traveller, or runner, having the lifting or hauling rope, which latter is wound upon a drum within the warehouse, attached to it, and this drum is capable of being revolved by a loose belt connection to a rotating shaft, which loose belt can be tightened when desired by a pressure pulley normally kept out of action by a counterweight. The lifting hook is attached to a frame suspended from the lifting or hauling rope, and provided with two arms sufficiently far apart to admit the carrier traveller or runner passing between them. Another pair of catches hinged to the jib hold the carrier traveller or runner in position, whilst the load is being lifted or lowered, by engaging with studs or projections on the carrier traveller or runner, and the abovementioned arms in rising are inclined by bevelled surfaces coming in contact with these studs so as to throw the hinged catches out of engagement, whilst catches upon the arms engage with them. The carrier traveller or runner and load can then be drawn up into the warehouse.

On the descent of the empty carrier, which takes place by gravity, the catches on the arms of the lifting hook are automatically disengaged, and the catches on the jib re-engage with the studs, so as to hold the carrier, traveller, or runner in position whilst the lifting hook is lowered into the hold of the vessel.

An arrangement of temporary rope-way for loading and unloading ships consists of a wire rope stretched taut between the deck of the vessel to be dealt with, and a crossbar, upon which a pulley is raised and lowered by a winch. This pulley is connected by a rope to a post, or other convenient point of attachment, situated somewhat beyond the place where it is desired to deposit the load, or to pick up the latter.

The carrier receptacle is first loaded in the lower position when the cargo of the vessel is being discharged, then the end of the rope is raised by means of the winch, and the carrier runs by gravity down the rope, is emptied, and the end of the rope being lowered, again returns by gravity. When the vessel is taking in cargo, and the load would be consequently running in the opposite direction, this operation is reversed.

## Installations for Hoisting and Conveying in America.

At the Tilly Foster Mines, in the State of New York, U.S., a wire rope-way* arranged to both hoist and convey loads, was employed for the removal of some 300,000 cubic yards of rock, in order to convert an old mine into an open pit, and uncover about 600,000 tons of ore. The excavation was about 450 feet in length by 300 feet in width, and the skip load of material had to be lifted up directly at the place where it might be filled. On the first erection of the line chain, connected fall-rope carriers were used to support the hoisting rope between the towers, and the carriage consisted of a series of blocks, with 8 or 10 inch wheels to run on the main carrying rope, spaced about every 50 feet, connected with ½-inch chains. These heavy and cumbersome fall-rope carriers were a source of considerable inconvenience. The hoisting rope only required to be supported every 100 feet, but with chain-connected carriers the chains themselves must be supported so as to be out of the way of obstructions below; in fact the chains must not hang lower than the skips, say 15 feet, thus bringing the carriers 20 to 30 feet apart. The weight of the chains and carriers was about 1 ton. The chains were found to swing about and get entangled in the fall-block and with each other, they limited the speed, gave rise to an abnormal amount of wear in the cable, added to the strain, and increased the power required in conveying the load fully 40 per cent. In spite of these

* A full description of this installation is given in a paper read before the Canadian Mining Institute in 1898 by Mr Spencer Miller, C.E.

drawbacks, however, each of the cable-ways was found capable of taking out 10 per cent. more loads per day than a derrick, whilst reaching out 300 feet against only 100 feet in the case of the latter.

Improved fall-rope carriers were subsequently introduced. An auxiliary rope, about $\frac{5}{8}$ inch in diameter, suspended above the main rope or cable, was held in a parallel position to the main cable by passing under wheels in the cable carriage, and had secured upon it a series of buttons, whose diameter increased with the distance from the head tower. Slots in the head of the carriers, corresponding to the diameter of the buttons, allowed each of the carriers in passing down the incline to be stopped at its proper button, the carriers having small wheels to roll upon the auxiliary or button rope. The heavy chains were thus dispensed with, and the fall-rope carriers spaced by buttons, and weighing in all about 100 lbs., took the place of the chain-connected carriers which, with the chain, weighed 2,000 lbs., and caused an increased strain on the anchorage of about 5 tons.

In another installation the button stop-rope carrier was applied to a horizontal line of wire rope-way of 855 feet span, which necessitated the provision of means for drawing the fall-rope carrier out with the carriage, as gravity could not be depended upon as in the previous case. For this purpose a horn, provided upon the carriage, both lifted the carriers bodily from the rope or cable so as to dispense with wheels on which the carrier might run on the main rope or cable, and also served to hold the carriers when distributing them along the cable; the carriers are again picked up by the horn on its return journey towards the engine or starting point. The buttons on the button rope take the carriers from the horn and leave them spaced along the main cable or rope at proper intervals for supporting the hoisting rope; the buttons increasing in size in a direction receding from the head tower, as also do the corresponding slots in the head of the top of the carrier. A standard pattern carriage and fall-rope carrier as used on above line is shown in Fig. 138.

The engine for driving has double cylinders fitted with reversible link motion. The drums are of large diameter and of the friction type, one carrying the hoisting rope, and the other turned with a curved surface carrying the endless rope, which latter is taken round it five or more times so as to ensure sufficient friction to secure immunity from slipping in the opposite direction to that in which the drum is turning, the ends of the rope are passed over the sheave wheels on the towers, and made fast to the front and rear wheels of the cable carriage. The hoisting drum is independent of the other, and being of the same diameter, winds at the same rate of speed, and keeps the load at the same height if so desired; it has also a band brake by means of which the load can be sustained. The reversing lever, and the friction and brake levers, are all brought to a central position so that the operator can work all of them without moving. The load can be hoisted or lowered at any point under the line of rope or cable.

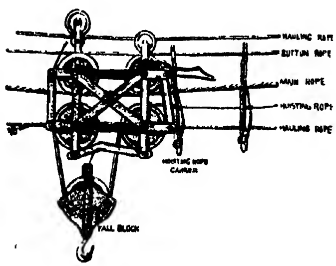


FIG. 138.--Installation for Hoisting and Conveying: Carriage and Fall Rope Carrier.

Further improvements that have been made in this installation consist, first, in the employment of an aerial dump, shown in Fig. 139, whereby the act of delivering the load from the skip at any point is performed automatically by the moving of a lever by the engineman, thus saving a man for releasing the load,

FIG. 139.—Installation for Hoisting and Conveying: Aerial Dump.

and also greatly reducing the time required for dumping the load; and secondly, in making the entire plant movable, which latter improvement has practically transformed the cable-way or aerial rope-way into a long distance travelling crane.

An installation of wire rope-way at one of the iron-ore mines in the Lake Superior district is fitted with a self-filling grab bucket, and two others are used to excavate sand from the bed of a river and deliver it to bins on dry land, where it is screened and shipped to St Louis. One of these plants has made as many as 33 trips in forty-four minutes, in actual working the number is from 30 to 40 trips per hour, or from 300 to 400 trips per day, the bucket having a capacity of $1\frac{1}{2}$ yards. The amount of material actually delivered is eighteen loads per day, averaging 18 yards per load, bringing the total up to 324 cubic yards; the labour required to deliver this amount of material being one engineman, one fireman, and one signalman.

An interesting type of wire rope-way for placer mining was erected at Alder Gulch, Montana, U.S. The objects of the installation were to excavate large quantities of material at a low cost per yard; to deliver the material at a sufficient height so that a gold-saving flume could be used of sufficient length and grade to thoroughly extract all the finer gold which escaped the original miners; and finally, to deliver the tailings at such an elevation that they would dispose of themselves.

The installation comprised a central tower containing a hopper, the bottom of which was 40 feet above the bed rock, and the dimensions of which were 27 by 16 by 8 feet, sloping from each side to a central channel 30 inches wide, which channel sloped back to the head of the flume or the gold-saving sluice. The A-shaped frame tail support, as originally constructed, being light and portable, could be easily shifted about the hopper as a centre; subsequently, however, this tail tower was mounted on wheels.

To dig the placer, a peculiar form of drag bucket was employed, which was carried over the point where the material was located, and then lowered to the ground, where it automatically settled into a position favourable for digging, the carriage being then run forward, leaving the bucket on the ground. When the direction of the ropes leading from the carriage to the bucket was favourable, the hoisting line was hauled in and the bucket dragged along the ground, teeth provided upon its edge ploughing into and cutting their way through the gravel, and the bucket becoming completely filled, after which it was hoisted, conveyed, and dumped automatically into the hopper.

The hopper tower was built of 8 by 8 inch timber, and at the top was placed an auxiliary tower, or bonnet, which supported the main rope or cable, and revolved to accommodate itself to the position of the latter. This was effected without disturbing the ropes leading from the head of the tower down between guiding sheaves to the engine.

A special form of engine was employed, having 10 by 12 inch cylinders, and drums 33 inches in diameter, the operating levers being arranged at the rear.

The main rope or cable was $1\frac{3}{4}$ inches in diameter, and of crucible steel.

This line actually handled over 400 buckets in ten hours, each bucket containing $1\frac{1}{2}$ yards of material, and in spite of the heavy cost of fuel and labour, the actual cost of the material handled did not exceed 3 cents per cubic yard. The labour required con-locking the guys in the required positions were provided. Two "fore-and-aft" guys were also supplied as "preventers," this arrangement being found more

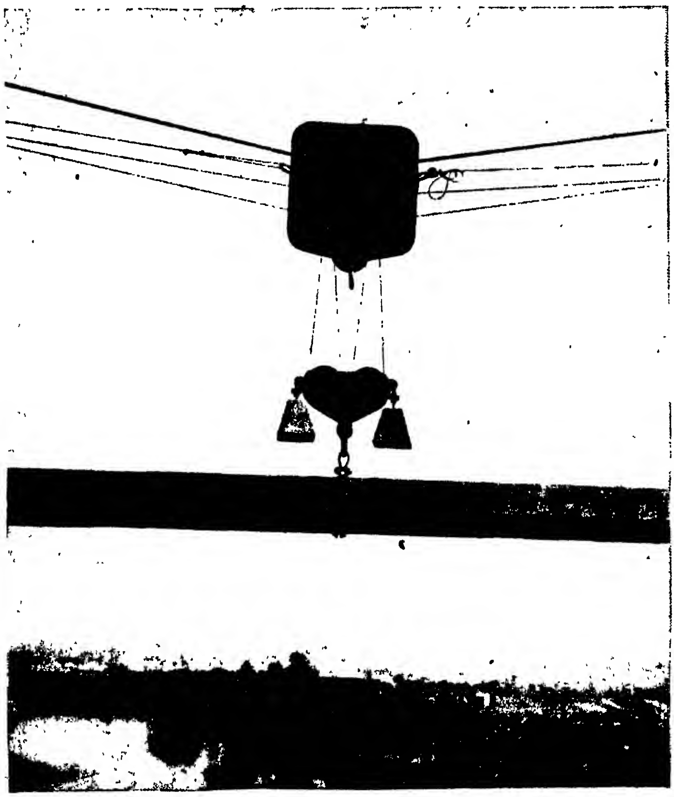


FIG. 141.—Wire Rope-Way for Hoisting and Conveying: Carrier or Running Head.

satisfactory and reliable than the usual clips for preventing any sliding of the derrick head on the main cables.

The main and other ropes or cables were all of

Bullivant's make: the first consisted of 4-inch, 6 by 17 specially selected mild steel wire rope having a breaking strain of 45 tons. The guys, $1\frac{3}{4}$-inch, 6 by 24 extra flexible steel wire crane ropes galvanised. The hoisting tackle, $1\frac{1}{2}$-inch, 6 by 24 extra flexible steel wire crane rope. The traversing gear, an endless $1\frac{1}{2}$-inch, 6 by 24 extra flexible steel wire rope.

The stress on the main cables or ropes was regulated by the centre deflections. The general loading rarely exceeded 3 tons, but at times the loads went up to $5\frac{1}{2}$ tons, which were handled with facility and despatch.

The cable-way over the permanent bridge was used for hoisting and setting steel plate girders of $5\frac{1}{2}$ tons each.

## Wire Rope-Ways for Coaling Vessels at Sea.

Experiments in coaling vessels at sea have been made for many years past, the subject being one of especial interest in relation to ships of war. According to Lieutenant C. E. Bell, R.N., in a paper read many years ago before the Royal United Service Institution, any satisfactory plan of coaling at sea must satisfy the following three absolutely essential requirements:—(1) Rapidity. (2) Safety. (3) Ability for the ships engaged in the operation to proceed with the minimum diminution of speed. Three further requirements of no little importance being:—(4) Necessity of keeping coal dry. (5) Minimum of labour to be employed. (6) Little cost of material necessitated.

It is generally admitted by all authorities upon the subject, says Lieutenant Bell, that coaling from broadside at sea is impossible, except in very calm devised by Lieutenant R. G. O. Tupper. As shown at B, Fig. 142, an endless rope is provided, starting from the stern of the collier in tow of the warship, passing over an elevated support on the foreyard, thence to the rear mast of the warship, and thence to the forepart of the latter. Buckets of coal are secured to this endless rope at close intervals, and the whole arrangement is worked by a capstan, the coal being passed in this manner from one ship to the other. The objection to Bell's plan obviously applies with equal force to the above.

The plan invented and patented in 1893 by the Hon. P. B. Low and illustrated at C, Fig 142, practically only differs from Bell's plan in that a counterweight is provided for maintaining a constant tension, and consequently a constant deflection, on the suspended cable regardless of the motion of the ships.

A test was made with this type of apparatus on board the two U.S. cruisers, "San Francisco" and the "Kearsarge." The distance from the shears of the cruisers to the upright poles on the collier was about 235 feet, so that the distance between the vessels was something less than 200 feet. The transporting cable was secured to the deck of the "San Francisco," supported by a pair of shear poles at the stern, then run on an incline to a gin block near the foremast of the "Kearsarge," which played the part of the collier, at an elevation of about 32 feet above the point of suspension on the "San Francisco." This gave an air line inclination from the points of support of about 8° to the horizontal. After the cable was rendered about the gin block it was bent backwards, and on the end was secured a counterweight of about 1,600 lbs. The bags of coal weighed nearly 200 lbs., and the time required to travel from the pole head on the collier to the shear pole on the warship was about fourteen seconds. The time occupied in hoisting and sending over ten bags of coal was about twenty minutes, giving the rate of from 2 to 2½ tons per hour. During the trial the sea was calm and the apparatus worked well. The Board of Naval Officers instructed to report on the trial, however, were of the opinion that in rough weather the apparatus would not be of any great value in transferring coal from one vessel to another. Great objections to this plan are:—Firstly, that in rough weather the distance between the vessels would have to be increased, the height of the gin block being also correspondingly increased to maintain a proper inclination and attaining an impracticable elevation; secondly, to render the capacity of the apparatus of practical service the loads would have to be far heavier, and to admit of this the weight of counterweight would have also to be increased and would become a source of danger.

A plan invented and patented by J. E. Walsh is shown at D, Fig. 142. The cable is attached at one end to the towing boat, inclines upward, and bends over a pulley block near the head of the foremast, thence bends under a pulley block carrying a counterweight. Overhead derricks are also shown in the drawing for hoisting the load out of both hatches to platforms on the masts, that on the mainmast being somewhat higher than that on the foremast, an auxiliary inclined cable being provided between the masts to carry the coal forward.

The objections urged against Low's plan apply equally in this case, indeed the carrying cable or rope being bent so many times would demand the use of a very large counterweight.

Two plans have been devised by S. Miller.

A.S.N.A. & M.E., the first of which is illustrated at E, Fig. 142. In the first arrangement shear poles are provided on one vessel and blocks on the mast of the other. An endless rope is employed, and a movable sheave in the bight of the cable aft is held taut by a line connecting it with a sea anchor or towing cone dragged in the sea behind the vessel. It will be seen that the vessel receiving the coal tows the sea anchor as well as the collier, the latter merely supporting the rope as it passes over. A carriage gripped to the upper part, and provided with wheels to roll on the lower part, serves to carry the bags of coal over from the collier to the vessel being coaled. An experimental trial of this arrangement was made with a tug towing a sloop, and although the test took place in a storm, the sloop shipping water over the bow, and both boats rolling and pitching very badly, the bags of coal were conveyed across the space (100 feet) as though the sea was smooth, the sea anchor serving to perfectly act as a compensator and maintaining a constant tension on the endless conveying cable. In practice the sea anchor would have to be selected in accordance with the speed of towing, the greater the speed the smaller the cone required.

The second arrangement is shown at F and G, Fig. 142, and in Fig. 143, as fitted on the U.S.S. "Marcellus." It is proposed, with this device, for the warship to take the collier in tow, or the collier to tow the warship, leaving the distance between the ships about 300 feet. On the deck of the warship to receive the coal a pair of shear poles secured by guys support a sheave wheel and a chute to receive the load. A special engine having two winding drums, shown more clearly in the detail view G, Fig. 142, is located aft of the foremast on the collier, and a steel cable ¾ inch

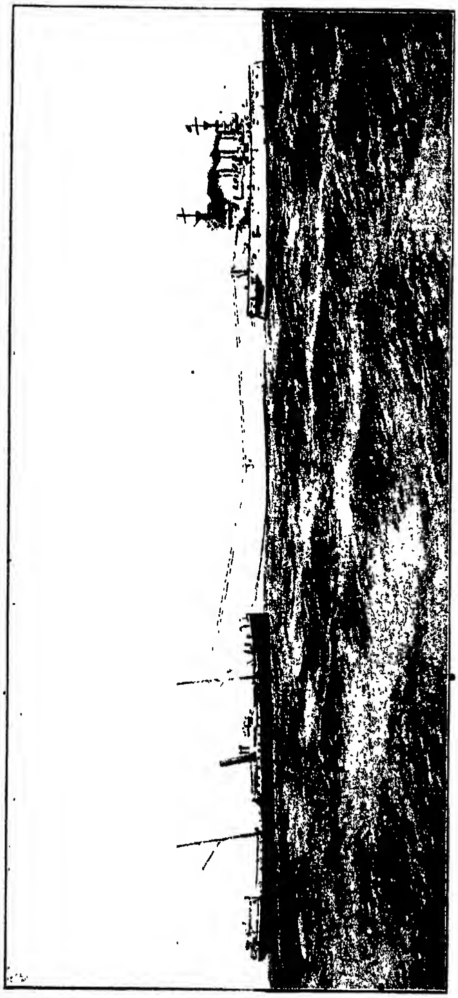


FIG. 143.—Practical Trial of Miller's Plan for Coaling Vessels at Sea.

diameter leads from one drum to the top of the fore-mast, over a sheave, thence to the sheave of the warship, back to another sheave on the top of the foremast, thence to the other drum. The engine imparts a reciprocating motion to the conveying rope, paying out one part under tension, a carriage secured to one of the parts passing to and from the warship, its load clearing the intervening water. The carriage, which conveys in bags a load of from 700 to 1,000 lbs., is fitted with wheels which roll on the lower part of the conveying cable or rope, and grip slightly but sufficiently the upper part of it. A hook pivoted at the bottom of the carriage and provided with a latch holds the load, and when the carriage comes in contact with a rubber buffer on the sheave block at the warship this latch is pressed in releasing the hook and its load. If the carriage strikes heavily at either terminus the upper part of the cable slips through the grip without damage. When the bags are dropped the direction of the rope is reversed and the carriage returned to the collier. During the transit of the load an elevator car descends to the deck, bags of coal suspended from a bale are placed on the elevator, and it is again raised to the stops on the guides where the pointed hook on the carriage finds its way under the bale or hanger supporting the coal bags, and the instant the load is hooked on, the direction of the ropes is again reversed and the carriage takes its load from the elevator, transfers it to the warship, and drops it again into the chute.

The engine for operating the conveyor runs practically all the time in one direction, its speed being varied by the use of the throttle. The drum near the foremast is provided with friction mechanism and operating lever, and is capable of giving to the rope a tension anywhere from 1,000 to 4,000 lbs. The other drum is provided with two dry metallic surfaces in contact and is adjusted to slip under any strain exceeding, say, 3,000 lbs. When the engine is running the tendency of both drums is to draw both parts in one to the extent of 4,000 lbs., and the other to 3,000 lbs. The effect consequently is that the 4,000-lbs. drum has a tendency to prevail and overhaul the 3,000-lbs. resistance, and it is this resistance that sustains the load during its transit. In this manner, through the co-operation of the two drums, the conveying distance between the two boats is compensated for and a practically uniform tension sustained during the transit of the load. On the points of support on the two ships approaching each other during the transit of the load, the drum pulling 4,000 lbs. will take up the slack and the 3,000-lbs. drum will temporarily cease slipping, or, at least, the amount of slip will be greatly reduced. Should the vessels pull apart, the 3,000-lbs. drum will simply slip the faster. It is only necessary to see that the speed of transit is in excess of double the speed at which the two vessels come together. After the load is dumped at the warship the operator releases the friction lever on the 4,000-lbs. drum, thus reducing the tension on the lower part to some point considerably below 3,000 lbs., whereupon the 3,000-lbs. drum acts to haul the rope and returns the carriage to the collier. The speed of conveying is about 1,000 feet per minute, thus a load can be taken from the collier and deposited in the warship in about twenty seconds.

Important features in the device are that the total tension on the two parts of the rope never exceeds about 8,000 lbs., and that should the ships pull away from each other and the tow-line part, the only effect will be to unwind the rope from one of the drums, its end falling into the water, the other drum then winding in the other end of the rope and recovering the carriage attached to it. The drum used for operating the conveyor also serves to wind up and store the cable when the collier is not coaling at sea.

Fig. 143 shows the collier actually in the act of coaling a warship.

Another system for coaling vessels at sea has lately been invented by Engineer-Commander Metcalfe, R.N., and a trial of the apparatus is reported to have recently been made in connection with the cruiser "Roxburgh," such weather conditions having been chosen as to render the test a severe one. The results of the trials, however, have not yet been made public.

An arrangement for coaling ships at sea, lately devised by M'Dowall & Piper, includes a conveyor which consists of an endless chain passing round shafts and provided with buckets, an endless operating chain passing round a sprocket wheel on one of these shafts and round a sprocket wheel on the conveyor frame, a bracket secured to the latter, a sprocket wheel on the bracket and about which the operating chain passes, and means for imparting motion to the operating chain.

Further particulars of wire rope-ways for hoisting and conveying will be found in a paper entitled "Aerial Suspension Cableways," by J. M. Henderson, A.M.I.C.E., *Proceedings of the Institution of Civil Engineers*, vol. clviii., pp. 188-222.

# CHAPTER VII

MISCELLANEOUS INFORMATION: TO CALCULATE THE STRAIN ON CARRYING ROPE—SPLICING AND SECURING WIRE ROPES—ORDINARY ROPE ATTACHMENTS—PRESERVING WIRE ROPES—GENERAL MATTERS.

**To Calculate the Strains on Carrying Rope.**—The following method is given in an article on wire rope-ways in the *Revue Mécanique*, Paris, by Messrs Thiery and Cretin, Professors at l'Ecole des Eaux et Forets.

(1) A cable or rope carried on two supports is only subjected to its own weight. Referring to Fig. 144, A B are the two fixed points supposedly at different levels, $c$ the length of the rope, $l$ and $h$ its horizontal and vertical projections, $\alpha$ its angle of inclination, T the tension exerted at the highest point A, $\beta$ its angle of inclination, $t$ the tension at the lowest point B. Admitting, according to general practice, that the weight of the cable is evenly distributed over the length $c$, although in reality it is distributed over the arc A M B, let $\omega$ be the weight of the rope per metre run, and $\omega_1$ be what it would be if it were distributed according to the arc, the total weight remaining the same.

Take any point C, $x$ and $y$ indicating the co-ordinates of that point in relation with the axes passing through A. The laws of equilibrium can be applied to the portion A C of the rope, the lower part C B being replaced by the tension C G exerted at C, the value of which may be represented by $\theta$. This is projected according to the tangent of the curve, and forms with the horizontal an angle $\gamma$. The equations of the projections on the axes of the co-ordinates give—

$$\theta \sin \gamma = T \sin \beta - \omega_1 \times \text{arc } AC.$$
$$\theta \cos \gamma = T \cos \beta.$$

Dividing we have—

$$tg\gamma = tg\beta - \frac{\omega x}{T \cos \alpha \cos \beta}.$$

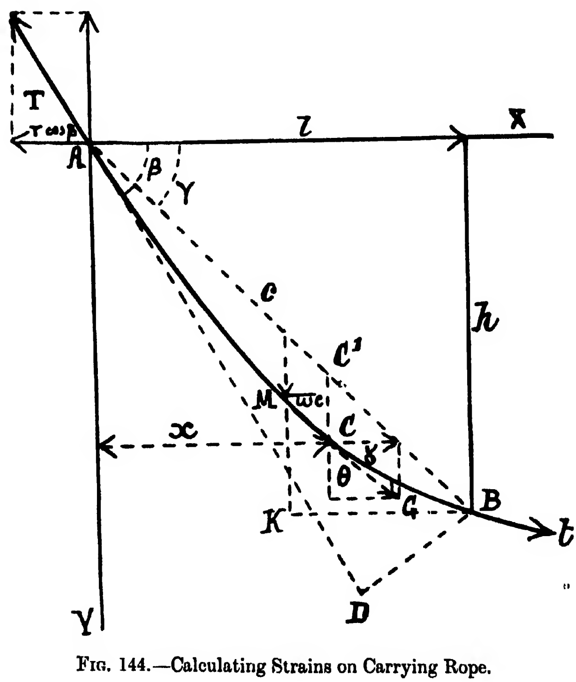



FIG. 144.—Calculating Strains on Carrying Rope.

The equation of projection on the axis of $x$ shows the horizontal component at any point on the cable to be constant and equal to T cos $\beta$. This being so the tension increases with the inclination of the tangent, or this latter, in accordance with the last equation, diminishes with $x$, T is therefore the maximum tension. To determine the latter the entire rope must be considered, and the sum of the moments of force T, $t$, and $\omega c$ be considered as *nil* as regards the point B. Taking the moment of the tension $t$ to equal zero, then—

$$T \times \overline{BD} - \omega c \times \overline{BK} = 0,$$

or

$$Tc \sin(\beta - \alpha) - \frac{\omega c t}{2} = 0;$$

from which

$$T = \frac{\omega t}{2 \sin(\beta - \alpha)},$$

or

$$T = \frac{\omega c \cos \alpha}{2 \sin(\beta - \alpha)}. \quad \text{- - - -} \quad (1)$$

If the cord A B is horizontal, the two tensions at A and B are equal and take, at these points, the maximum value.

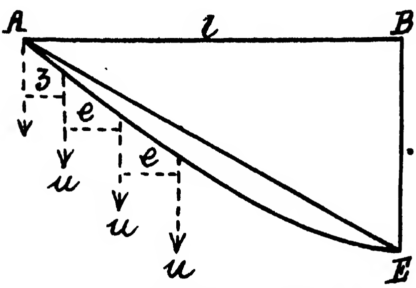



FIG. 145.—Calculating Strains on Carrying Rope.

(2) Given a rope suspended from two supports and carrying a number of loads $n$ equal and at the same distance from each other, Fig. 145. Let the value of one of these loads be $\mu$, $e$ the horizontal distance between them, and $z$ the horizontal distance at point A. Taking the moments of all the forces in respect to point E,

be increased, so changing the angle $\beta$, or the distance between the loads be altered, fresh calculations must be made.

The value of angle $\beta$ may be obtained in several ways. By photography, a sensitive plate being placed parallel to the vertical plane of the rope, the optical axis of the objective being normal to this plane. Or, as shown in Fig. 147, wherein A is the highest point of the rope.

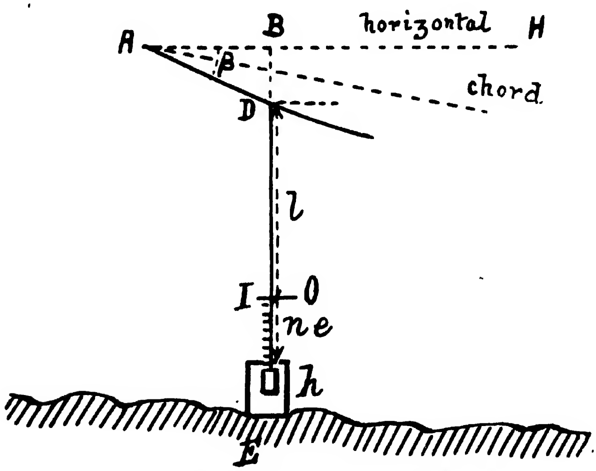



FIG. 147.—Calculating Strains on Carrying Rope.

Take an arc A D, and at D attach a plumb-line, the bob of which hangs in a tube to prevent oscillation. This plumb-line is graduated, as at I. If $l$ be the constant length, $h$ be the height of the tube, and $e$ the value of one division of the graduations I, and say, for example, that the division $n$ is found to agree with the upper end of the tube, the height D E will be equal to $(l+h)+ne$. The height B E being known, B D can be deduced. A D is measured and the angle $\beta$ calculated by its sine.

## Table of Coefficients of Inclination.

| Values of α. | Values of (β − α) in Degrees. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 57·3 | 28·7 | 19·1 | 14·3 | 11·5 | 9·6 | 8·2 | 7·3 | 6·4 | 5·8 |
| 2 | 57·3 | 28·7 | 19·1 | 14·3 | 11·5 | 9·6 | 8·2 | 7·2 | 6·4 | 5·8 |
| 3 | 57·2 | 28·6 | 19·1 | 14·3 | 11·5 | 9·6 | 8·2 | 7·2 | 6·4 | 5·8 |
| 4 | 57·2 | 28·6 | 19·1 | 14·3 | 11·4 | 9·5 | 8·2 | 7·2 | 6·4 | 5·7 |
| 5 | 57·1 | 28·5 | 19·0 | 14·3 | 11·4 | 9·5 | 8·2 | 7·2 | 6·4 | 5·7 |
| 6 | 57·1 | 28·5 | 19·0 | 14·3 | 11·4 | 9·5 | 8·2 | 7·1 | 6·4 | 5·7 |
| 7 | 57·0 | 28·4 | 19·0 | 14·2 | 11·4 | 9·5 | 8·1 | 7·1 | 6·3 | 5·7 |
| 8 | 56·9 | 28·4 | 18·9 | 14·2 | 11·4 | 9·5 | 8·1 | 7·1 | 6·3 | 5·7 |
| 9 | 56·8 | 28·3 | 18·9 | 14·2 | 11·3 | 9·4 | 8·1 | 7·1 | 6·3 | 5·7 |
| 10 | 56·6 | 28·2 | 18·8 | 14·1 | 11·3 | 9·4 | 8·1 | 7·1 | 6·3 | 5·7 |
| 11 | 56·4 | 28·1 | 18·8 | 14·1 | 11·3 | 9·4 | 8·0 | 7·0 | 6·3 | 5·6 |
| 12 | 56·2 | 28·0 | 18·7 | 14·0 | 11·2 | 9·4 | 8·0 | 7·0 | 6·3 | 5·6 |
| 13 | 56·0 | 27·9 | 18·6 | 14·0 | 11·2 | 9·3 | 8·0 | 7·0 | 6·2 | 5·6 |
| 14 | 55·8 | 27·8 | 18·6 | 13·9 | 11·1 | 9·3 | 7·9 | 7·0 | 6·2 | 5·6 |
| 15 | 55·5 | 27·7 | 18·5 | 13·8 | 11·1 | 9·2 | 7·9 | 6·9 | 6·2 | 5·6 |
| 16 | 55·2 | 27·6 | 18·4 | 13·8 | 11·0 | 9·2 | 7·9 | 6·9 | 6·1 | 5·5 |
| 17 | 54·9 | 27·4 | 18·3 | 13·7 | 11·0 | 9·1 | 7·8 | 6·9 | 6·1 | 5·5 |
| 18 | 54·6 | 27·2 | 18·2 | 13·6 | 10·9 | 9·1 | 7·8 | 6·8 | 6·1 | 5·5 |
| 19 | 54·3 | 27·1 | 18·1 | 13·5 | 10·8 | 9·0 | 7·7 | 6·8 | 6·0 | 5·4 |
| 20 | 54·0 | 26·9 | 18·0 | 13·5 | 10·8 | 9·0 | 7·7 | 6·7 | 6·0 | 5·4 |
| 21 | 53·7 | 26·8 | 17·8 | 13·4 | 10·7 | 8·9 | 7·6 | 6·7 | 6·0 | 5·4 |
| 22 | 53·3 | 26·6 | 17·7 | 13·3 | 10·6 | 8·9 | 7·6 | 6·6 | 5·9 | 5·3 |
| 23 | 52·9 | 26·4 | 17·6 | 13·2 | 10·6 | 8·8 | 7·5 | 6·6 | 5·9 | 5·3 |
| 24 | 52·5 | 26·2 | 17·5 | 13·1 | 10·5 | 8·7 | 7·5 | 6·6 | 5·8 | 5·3 |
| 25 | 52·1 | 26·0 | 17·3 | 13·0 | 10·4 | 8·7 | 7·4 | 6·5 | 5·8 | 5·2 |
| 26 | 51·6 | 25·7 | 17·2 | 12·9 | 10·3 | 8·6 | 7·4 | 6·5 | 5·7 | 5·2 |
| 27 | 51·2 | 25·5 | 17·0 | 12·8 | 10·2 | 8·5 | 7·3 | 6·4 | 5·7 | 5·1 |
| 28 | 50·7 | 25·3 | 16·9 | 12·6 | 10·1 | 8·5 | 7·2 | 6·3 | 5·6 | 5·1 |
| 29 | 50·3 | 25·1 | 16·7 | 12·5 | 10·0 | 8·4 | 7·2 | 6·3 | 5·6 | 5·0 |
| 30 | 49·8 | 24·8 | 16·6 | 12·4 | 9·9 | 8·3 | 7·1 | 6·2 | 5·5 | 5·0 |

## Table of Coefficients of Inclination—*Contd.*

| Values of α. | Values of (β − α) in Degrees. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 1 | 5·2 | 4·8 | 4·4 | 4 1 | 3·9 | 3·7 | 3·5 | 3·3 | 3·1 | 2·9 |
| 2 | 5·2 | 4·8 | 4·4 | 4·1 | 3·9 | 3·6 | 3·4 | 3·2 | 3·1 | 2 9 |
| 3 | 5·2 | 4·8 | 4·4 | 4·1 | 3 9 | 3·6 | 3·4 | 3·2 | 3·1 | 2·9 |
| 4 | 5·2 | 4·8 | 4·4 | 4·1 | 3·9 | 3·6 | 3·4 | 3·2 | 3·1 | 2 9 |
| 5 | 5·2 | 4·8 | 4·4 | 4·1 | 3·9 | 3·6 | 3·4 | 3·2 | 3·1 | 2·9 |
| 6 | 5·2 | 4·8 | 4·4 | 4·1 | 3·8 | 3·6 | 3·4 | 3·2 | 3·0 | 2·9 |
| 7 | 5 2 | 4·8 | 4·4 | 4·1 | 3·8 | 3·6 | 3·4 | 3·2 | 3·0 | 2·9 |
| 8 | 5·2 | 4·8 | 4·4 | 4·1 | 3·8 | 3·6 | 3·4 | 3·2 | 3 0 | 2·9 |
| 9 | 5·2 | 4·7 | 4·4 | 4·1 | 3·8 | 3·6 | 3 4 | 3·2 | 3·0 | 2·9 |
| 10 | 5·2 | 4·7 | 4·4 | 4·1 | 3 8 | 3·6 | 3·4 | 3·2 | 3·0 | 2·9 |
| 11 | 5·1 | 4·7 | 4·4 | 4·1 | 3·8 | 3·6 | 3·4 | 3·2 | 3·0 | 2·9 |
| 12 | 5·1 | 4·7 | 4·3 | 4·0 | 3·8 | 3·6 | 3·3 | 3·2 | 3 0 | 2·9 |
| 13 | 5·1 | 4·7 | 4·3 | 4·0 | 3·8 | 3·5 | 3·3 | 3·1 | 3·0 | 2·8 |
| 14 | 5·1 | 4·7 | 4·3 | 4·0 | 3·8 | 3·5 | 3·3 | 3·1 | 3·0 | 2·8 |
| 15 | 5·1 | 4·6 | 4·3 | 4·0 | 3·7 | 3·5 | 3·3 | 3·1 | 2·9 | 2·8 |
| 16 | 5·0 | 4·6 | 4·3 | 4·0 | 3 7 | 3·5 | 3 3 | 3·1 | 2·9 | 2·8 |
| 17 | 5·0 | 4·6 | 4·3 | 4·0 | 3·7 | 3·5 | 3·3 | 3·1 | 2·9 | 2·8 |
| 18 | 5·0 | 4·6 | 4·2 | 4·0 | 3·7 | 3·5 | 3·3 | 3 1 | 2·9 | 2·8 |
| 19 | 5·0 | 4·5 | 4·2 | 3·9 | 3·7 | 3·4 | 3·3 | 3·1 | 2·9 | 2·7 |
| 20 | 4·9 | 4·5 | 4·2 | 3·9 | 3·6 | 3·4 | 3 2 | 3·0 | 2 9 | 2·7 |
| 21 | 4·9 | 4·5 | 4·2 | 3·9 | 3·6 | 3·4 | 3·2 | 3·0 | 2·8 | 2·7 |
| 22 | 4·8 | 4·5 | 4·1 | 3·8 | 3·6 | 3·4 | 3·2 | 3·0 | 2·8 | 2·7 |
| 23 | 4·8 | 4·4 | 4·1 | 3·8 | 3·6 | 3·4 | 3·2 | 3 0 | 2·8 | 2·7 |
| 24 | 4·8 | 4·4 | 4·1 | 3·8 | 3·5 | 3·3 | 3·1 | 3·0 | 2·8 | 2·7 |
| 25 | 4·7 | 4·4 | 4·0 | 3·7 | 3·5 | 3·3 | 3·1 | 2·9 | 2·8 | 2·6 |
| 26 | 4·7 | 4·3 | 4·0 | 3·7 | 3·5 | 3·3 | 3·1 | 2·9 | 2 8 | 2·6 |
| 27 | 4·7 | 4·3 | 4·0 | 3·7 | 3·4 | 3·2 | 3·1 | 2·9 | 2·7 | 2·6 |
| 28 | 4·6 | 4·2 | 3·9 | 3·6 | 3·4 | 3·2 | 3·0 | 2·9 | 2·7 | 2·6 |
| 29 | 4·6 | 4·2 | 3·9 | 3·6 | 3·4 | 3·2 | 3·0 | 2·8 | 2·7 | 2·6 |
| 30 | 4·5 | 4·2 | 3·9 | 3·6 | 3·3 | 3 2 | 3·0 | 2·8 | 2·7 | 2·5 |

## Splicing Wire Ropes.

The splicing or otherwise securing together of the ends of wire ropes, and the fastening of rope attachments to the ends of such ropes, forms an important feature in their use in connection with aerial or wire rope-ways.

To commence with the operation of splicing, a six-strand wire rope is that which allows of the most perfect and neatest splice being made, inasmuch as the strands are then the exact size of the core of the rope, for which they can be readily substituted when the latter has been removed to admit of the strands taking its place.

A five-strand rope forms, however, a very strong splice, because of the strands being somewhat larger than the core of the rope, and consequently in the finished splice the exterior strands gripping or pressing very firmly upon the inserted strands, and tending to prevent the splice from drawing. A drawback to this splice, however, is that the bending of the rope round a pulley frequently causes the strands to protrude.

When forming a splice every precaution should be taken to see that no ends are left projecting, or no thick parts formed in the rope.

The first thing to be done is to bring the two extremities of the rope taut and overlapping some 20 feet by means of a block and fall. About 10 feet of each end must then have the strands opened and the core or centre cut off closely, and the bunches of strands brought opposite to each other as shown in Fig. 148, so that the opposite strands may interlock regularly with one another.

Next, unlay the strand marked *a* of one rope end, and follow up with the strand marked 1 of the other rope end, laying it tightly into the groove left open by the unwinding or unlaying of the strand *a*, causing the twist of the strand to correspond exactly with the lay of the open groove, until the whole of strand 1, up to about 6 inches, has been laid in, and strand *a* has become 20 feet long. Then cut strand *a* off within 6 inches of the rope, leaving two short ends, as shown in Fig. 149, which ends should be temporarily secured by tying.

Now unlay the strand marked 4 of the opposite rope

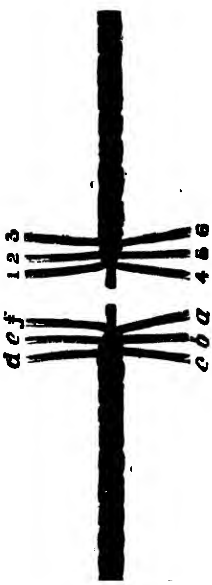


Fig. 148.—Splicing Wire Ropes: First Operation.

Fig. 149.—Splicing Wire Ropes: Second Operation.

Fig. 150.—Splicing Wire Ropes: Third Operation.

end, following it up with the strand marked *f* laid into the open groove as above described, and treat in an exactly similar manner; following likewise the same procedure with the strands marked *b* and 2, but stopping within 4 feet of the first set, then with the strands marked *e* and 5, *c* and 3, and *d* and 6, when all the strands will be laid into each other's places with their respective ends passing each other at points 4 feet apart as shown in Fig. 150.

Lastly, to secure and dispose of the ends without increasing the diameter of the rope, these ends should be well straightened and lapped with fine hemp siezing, a marlinspike should be inserted through the centre of the rope, and 6 inches of the core or centre cut out, the end of 1 being then placed under *a* and tucked into the space previously occupied by the core, and a 6-inch length of core being cut out on the other side, the end of *a* should be inserted into its place in the same way. The other ends should then be disposed of in a similar manner, taking an end alternately from one side and then from the other.

Finish off the splice by well closing the rope, and removing any unevenness or irregularity by hammering with a wooden mallet.

Additional strength may be ensured by passing the end of No. 1 strand over strand *a*, and strand *b* over strand No. 1, by which a very tight grip is obtained, and the splice rendered capable of withstanding very severe strains.

## Securing Wire Ropes in Sockets, &c.

As regards methods for securing the ends of wire ropes together by means of sockets, and of fastening them to various attachments in common use, numerous plans have been devised, some of which have been briefly alluded to when describing certain particular installations, and the following are a few amongst the many others.

R. S. Newall, as far back as 1840, provided for securing the ends of wire ropes by passing each end into and through a conical thimble, doubling back the ends of the strands and pulling back the rope until the doubled part fits the thimble, when by pouring melted brass amongst the ends of the strands they are prevented from being drawn out of the thimble. The two ends having been thus secured in their respective thimbles, the latter are screwed together by means of a right and left handed screwed connecting piece, and are fixed or locked in place by means of pins. A hook or an eye may be fastened to the rope in a like manner.

A socket for wire ropes which is fairly satisfactory consists of a taper or conical cap made of iron or steel and fitted with a soft metal lining, which cap is placed round the rope end. The rope end is then brought into proper position and forcibly driven outwards against the lining within the socket, a taper plug or wedge also made of soft metal similar to the lining being inserted to hold the wire ends asunder. A bolt is also fitted which is intended to carry the load, or to connect another socket, and which passes through a double eye. This device possesses the advantage of admitting of the process of socketing being easily and rapidly performed.

Another good form of socket consists essentially of a taper or conical iron, steel, or other metal socket piece, the internal diameter of the smaller end of which is somewhat larger than the circumference or girth of the rope to be secured in it. Taper or conical wedge or locking pieces are placed round the end of the rope, which wedges are of such dimensions that when the rope is drawn tight into position in the socket, and the wedge pieces jammed between the inner face of the former and the rope, they will be at a certain distance from the smaller end of the socket. The result of this arrangement is that the more the force exerted to draw the rope from the socket, the tighter will the wedge or locking pieces become jammed and tend to hold it in place therein. The surfaces of the wedge or locking pieces next the rope may be serrated or roughened, and sufficient clearance should be provided between them to admit of their tightening upon the rope as the latter becomes compressed through the pressure exerted upon it.

In an arrangement somewhat resembling the above the wedges are constructed in two parts, the one outside the other, the outer face of the inner part having rounded projections adapted to fit into corresponding recesses in the inner face of the outer part. The component wires of the rope are bent over the end of the inner part, and will be firmly gripped between the two parts when the wedges become jammed in the tapered casing or socket.

The following plans may also be mentioned:—

Wedge-shaped toothed clips, placed one on each side of the rope, are surrounded by a ring, within which is placed a bridle with shoulders to bear against the ring, the strain upon the bridle tightening the wedges on the rope.

Passing the wires through a cone, turning them over, winding round the parallel layers, and fastening the ends to the rope. This cone is then placed in a socket and a ring or hook screwed in, the end of the cone being protected by a leather disc.

Clamping the rope ends between grooved plates by screw bolts passed through the edges of the plates, or by means of a single bolt longitudinally slotted to receive the rope ends. In the first arrangement a grooved tapering block is preferably inserted between one of the plates and the ropes.

Baring the rope end for a short distance, and passing an internally tapered and externally screwed ferrule over it. An expander being then driven into the end of the rope, and a cap screwed on to the ferrule.

Bleichert proposes to secure a shackle to the end of a wire rope by fitting the end of the latter, previously tinned, into a conical bush, distending the ends of the wires forming the rope, and filling the space between them with a composition of hard tin. The shackle is screwed on to the exterior of the bush.

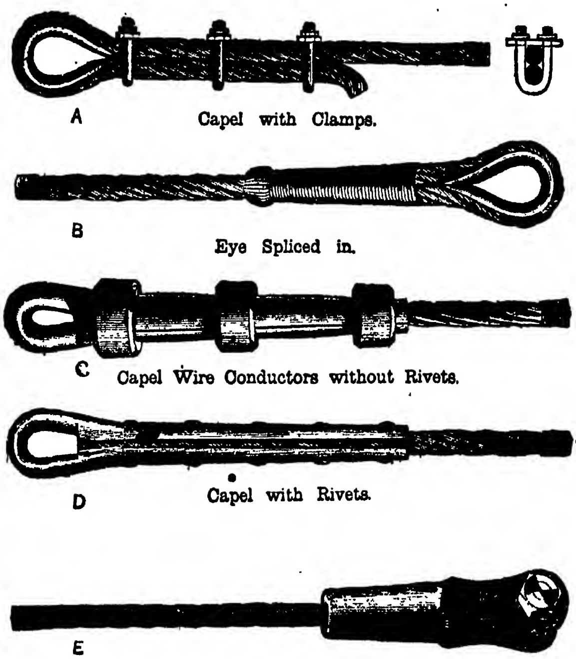
To connect together the ends of wire ropes, the adjacent ends of the ropes are tinned and placed in conical bushes, the ends of the wires are then bent apart, the whole warmed in red-hot pincers, and the ends cast out solid with a composition of hard tin, after which the bushes are screwed to a central connecting piece.

This is practically the same method of securing the end of a wire rope in a socket as that devised nearly sixty years ago by Newall, which has been already described.

## Ordinary Rope Attachments.

A, B, C, D, and E, Fig. 151, illustrate the ordinary forms of wire rope attachments in most general use. A shows an arrangement of clamps with capel. The end of the rope, it will be seen, is merely bent round a gimbal ring or eye, and then covered with the clamps. B is a capel; the eye is in this case spliced in as shown. C is a socket with hoops or rings, which latter are driven on hot to shrink and tighten when cold. D is a riveted socket, and E is a conical socket.

In the case of the three latter arrangements the



A Capel with Clamps.

B Eye Spliced in.

C Capel Wire Conductors without Rivets.

D Capel with Rivets.

E Conical Socket without Rivets.

FIG. 151.—Ordinary Forms of Wire Rope Attachments.

end of the rope must be somewhat enlarged to a conical shape, which can be conveniently effected by turning back the wires layer by layer, and binding them down with copper wire. As the first layers will be the longest, and the others successively shorter, the desired conical shape will be ensured.

In the conical socket E the rope is first passed through the bore in the head, enlarged as above described, and drawn back until the conical enlargement engages in the conical portion of the bore.

## Preserving Wire Ropes.

An important point in connection with the working of aerial or wire rope-ways is the lubrication and other means to be adopted for preventing premature decay of the wire ropes.

As regards the preservative treatment most suitable for running and other wire ropes it may be summed up in a few words to consist essentially in a sufficiently abundant lubrication with a suitable oil, grease, or other medium, at frequent and regular intervals.

A great portion of the wear of the rope is due to the cutting action of the wires against one another, and this action can only be reduced by a judicious application of an oil capable of permeating the rope.

Tests have demonstrated that an oiled rope will stand from two to five times more bends than the same rope unoiled.

The best unguent to employ is a matter upon which some difference of opinion exists. One authority states* that he has found from practical experience on a wire rope-way, extending over a number of years, the best lubricant to be black West Virginia oil fed on to the rope by automatic lubricators, about 3 gallons per month being used in this case on a line of about 2 miles in length. "On first starting working the line in question Swedish tar mixed with boiled

* See pp. 110, 111.

linseed oil was tried with inferior results in every way.

Linseed oil by itself is also recommended.

The following have also been employed or recommended for the preservation or prevention of the premature decay of wire ropes:—

The application of a coating of a mixture composed of 6 parts of tar, 2 parts of linseed oil, and 2 parts of tallow, melted and mixed together, and applied to the rope whilst hot.

A coating of a solution of caoutchouc in caoutchoucine.

Passing the strands and the rope after closing through receptacles containing mica grease, glissantoline, &c., to protect the core and the strands from corrosion.

Winding a zinc wire between the steel wires to prevent rusting of the latter.

Depositing on the rope a coating of cadmium by electrolysis in a bath of ammonium sulphate, or of the double salt of cyanide of cadmium and cyanide of potassium, the anodes being of rolled cadmium; a coating of zinc, &c., being sometimes first deposited on the rope and afterwards a coating of cadmium, or the operation reversed.

A number of machines have been devised for cleaning wire ropes and for lubricating them, and the use of some efficient cleaning and lubricating machine in connection with a running wire rope is very desirable, as the practice of applying the fresh lubricant upon the uncleaned rope, and over the previously applied oil, is not only extremely wasteful, but, owing to the possible defects in the rope being thus concealed from view, is one fraught with much danger.

One type of apparatus designed for cleaning and lubricating wire ropes comprises circular or cylindrical wire or hair brushes keyed on axles carried in a vertical frame, and two plain rollers which have spur or toothed wheels attached to them gearing with other spur or toothed wheels secured to the wire or hair brushes. The bearings are made movable to allow of the introduction of the rope between the brushes, and screws for regulating the pressure of the brushes, and rollers engaging the rope are also provided; the frictional contact of the rollers against the rope imparts the necessary rotary motion to the circular brushes. As soon as the rope has been satisfactorily cleaned the wire brushes are removed, and are replaced by hair brushes, or the latter are replaced by barrels or drums covered with spongy material and kept supplied with lubricant from an oil reservoir, box, or hopper, or the brushing and lubricating operations may be performed simultaneously instead of separately.

Another pattern of wire-rope cleanser and lubricator, and one which is said to give very good results, is that known as the *vacuum*. This apparatus, which is chiefly characterised by its extreme simplicity, consists of a spherical oil-box constructed in halves, and surmounted by a gallery or ring running through small wheels or rollers upon a circular path or race on the oil-box. This gallery or ring contains a series of radially adjustable wire brushes, the points of which are pressed in between the strands of the rope, and the spherical oil-box is formed with axial holes to admit of the passage of the rope, a hinge joint being provided upon one side and a screw fastening on the other.

When the device is placed in position on the wire rope, the latter will pass axially through the spherical oil-box and brush gallery or ring, and when the oil-box is secured, and the rope travels through it, the gallery or ring will be caused to revolve, and all the accumulations of dirt and gummy oil will be scraped off and removed, falling down outside the box.

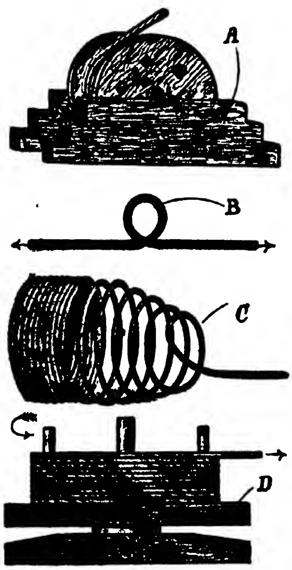
The outlets of the oil-box are provided with stuffing boxes fitted with split indiarubber packing rings, and the arrangement is such that a suitable amount of oil will be allowed to pass away with the rope.

The oil can be inserted into the box, the two parts or halves of which form a fluid tight joint when closed, through apertures fitted with screw plugs.

## GENERAL MATTERS.

### Directions for Uncoiling Wire Ropes.

SMALL ropes or cables are delivered in coils wrapped in canvas, heavy ropes or cables are coiled on a reel covered with wooden staves.




FIGS. 152, 153, 154, and 155.
Methods of Uncoiling Wire Rope.

To uncoil a rope off a reel the latter should be mounted in bearings in a frame A as shown in Fig. 152, and the rope wound off carefully on to the drum, great care being taken to avoid the occurrence of a kink as shown at B, Fig. 153, which is a serious matter in a wire rope, and likely to remain always a weak place during the life of the rope.

Coils of rope should never be uncoiled by hand in the manner indicated at C, Fig. 154; they should be placed on a wheel as shown at D, Fig. 155, so that the whole coil can be turned during coiling off.

## To Remove a Kink from a Wire Rope.

In transporting wire ropes in mountainous districts, more especially when such transportation has to be effected upon the backs of mules,* they are very liable to get kinked.

To remove a short kink successfully it is recommended to fasten two clamps to the rope, one on either side of the kink, with just room to use a mallet freely. Then by unbending the kink in the direction in which it is formed, whilst at the same time twisting the rope with the clamps into proper shape, and setting down with a mallet, the worst kink can be taken out so that it cannot be noticed. Trying to pull or hammer out a kink will only make it worse, and weaken the rope more than if it were left in.

## Estimate for Wire Rope-Way.

The following particulars are recommended by Mr Carrington to be sent when a definite estimate for a wire rope-way is required:—

Length of line from end to end.

Does the line go straight from end to end? If not, state the number and degrees of angles.†

Approximate section of ground to be passed over?‡

The quantity to be carried per hour, and the character of material to be transported?

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* See p. 109.

† It is recommended in all cases where possible that the rope-ways should run in a straight line from end to end. See p. 14.

‡ If possible a detailed section should be sent, but in many cases a simple pen and ink sketch giving the leading dimensions is sufficient.

Is steam or water power available, and if so, state amount?

Is timber available on the spot for the construction of terminal frames and posts? *

For the guidance of those getting out such particulars, it may be stated that any divergence from the straight line should be made in the form of an angle, and not in a curve; and where motive power is available at the point where this divergence is made, the angle can be constructed without additional cost.

Where possible it is preferred to place the driving power at the delivering terminus of the rope-way, but this is not essential.

The most convenient apportionment of the loads is as follows:—

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| For a | 50 | ton line | 100 | lbs. to | 120 | lbs. load. |
| ,, | 100 | ,, | 120 | ,, | 170 | ,, |
| ,, | 200 | ,, | 170 | ,, | 250 | ,, |
| ,, | 300 | ,, | 400 | ,, | 440 | ,, |

These loads are not absolutely necessary, but when adopted will enable the cheapest form of rope-way to be used.

## Approximate Price List for Wire Rope-Ways on the Carrington Endless-Rope System.

The following list will enable the reader to form an idea of the cost of any rope-way he may contemplate erecting, but as the price varies greatly according to the ground passed over and the material to be transported, it must be borne in mind that the amounts given are purely approximate.

* The above portions are recommended to be constructed in timber, but where necessary can be supplied in iron or steel.

| | 50 Ton per Ten Hours Line. | 100 Ton per Ten Hours Line. | 200 Ton per Ten Hours Line. |
|---|---|---|---|
| | £ | £ | £ |
| 1. Rope, pulleys, and rolling stock for a length not exceeding 1 mile, per mile | 310 | 460 | 580 |
| 2. Driving and tightening gears with shunt rails for a rope-way, 1 mile or less in length | 60 | 130 | 170 |
| 3. Rope, pulleys, and rolling stock for a length not exceeding 3 miles, but over 1 mile, per mile | 340 | 490 | 620 |
| 4. Driving and tightening gears with shunt rails for a rope-way not exceeding 3 miles in length, but over 1 mile | 120 | 250 | 300 |
| 5. Angles giving any degree of deviation, each | 25 | 35 | 45 |
| 6. Packing, &c., about | 20 to 30 | 30 to 40 | 40 to 50 |

To which must be added the cost of wood posts and engine power. The former average about thirty per mile, and on level ground are about 15 feet high, costing from £4 to £5 each; irregularities of level will cause a corresponding variation in the heights of the posts.

The amount of engine power necessary varies under all circumstances. Reference to the descriptions of lines at work will give a fair idea of the power required for various services.

It must be understood that the wood frames for carrying the terminal gears and shunt rails are not included in the above prices. But otherwise these prices would usually be found to be rather in excess of a final estimate made on receipt of full particulars.

Rope-ways for lengths under half a mile should be specially estimated for.

To illustrate the proper method of estimating from above prices, the following examples will be found useful, viz. :—

1. Cost required for a rope-way three-quarters of a mile long to carry 50 tons per ten hours with one angle.

Rope, pulleys, and rolling stock as per No. 1, £310 per mile, or for three-quarters of a mile, £232. 10s., and terminal gear, &c., as per No. 2, £60, and with curve as per No. 5, £25. Total cost, £317. 10s.

2. Cost required of a rope-way 2 miles long to carry 100 tons per ten hours as per No. 3. Rope, pulleys, and rolling stock will cost £980, and as per No. 4, driving gear, &c., will cost £250. Total, £1,230.

Packing is only necessary for export.

The cost of several of the different installations described in previous chapters has been also given, which will assist in forming a rough estimate of the probable outlay that would be required for the erection of a wire rope-way in various situations, and to perform certain specific duties, and the working expenses of the lines which have been likewise added, in several instances, will enable an idea to be gained of the possible saving, in the cost of the transportation of materials, that could be effected by the use of an aerial or wire rope-way.

## Horse-Power Necessary to Propel 1,000 lbs. at Various Speeds and up Various Grades at Same Speeds.

(Consolidated Telpherage Company.)

The traction per 1,000 lbs. assumed in this table is 10 lbs. On any but a very good rail the traction will be more than this, and the power required by

| Grades in Per Cent. | Speed in Miles per Hour. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 15 | 20 | 25 |
| 0 | ·027 | ·053 | ·080 | ·107 | ·133 | ·160 | ·187 | ·213 | ·240 | ·267 | ·320 | ·400 | ·533 | ·667 |
| 1 | ·053 | ·107 | ·160 | ·213 | ·267 | ·320 | ·373 | ·427 | ·480 | ·533 | ·640 | ·800 | 1·07 | 1·33 |
| 2 | ·080 | ·160 | ·240 | ·320 | ·400 | ·480 | ·560 | ·640 | ·720 | ·800 | ·960 | 1·20 | 1·60 | 2·00 |
| 3 | ·106 | ·213 | ·320 | ·427 | ·533 | ·640 | ·747 | ·853 | ·960 | 1·07 | 1·28 | 1·60 | 2·13 | 2·67 |
| 4 | ·133 | ·267 | ·400 | ·533 | ·667 | ·800 | ·933 | 1·07 | 1·20 | 1·33 | 1·60 | 2·00 | 2·67 | 3·33 |
| 5 | ·160 | ·320 | ·480 | ·640 | ·800 | ·960 | 1·12 | 1·28 | 1·44 | 1·60 | 1·92 | 2·40 | 3·20 | 4·00 |
| 6 | ·186 | ·373 | ·560 | ·747 | ·933 | 1·12 | 1·30 | 1·49 | 1·68 | 1·87 | 2·24 | 2·80 | 3·73 | 4·67 |
| 7 | ·215 | ·427 | ·640 | ·853 | 1·07 | 1·28 | 1·49 | 1 71 | 1·92 | 2·14 | 2·56 | 3·20 | 4·27 | 5·33 |
| 8 | ·241 | ·480 | ·720 | ·960 | 1·20 | 1·44 | 1·68 | 1·92 | 2·16 | 2·40 | 2·88 | 3·60 | 4·80 | 6·00 |
| 9 | ·267 | ·533 | ·800 | 1·07 | 1·33 | 1·60 | 1·87 | 2·13 | 2·40 | 2·67 | 3·20 | 4·00 | 5·33 | 6·67 |
| 10 | ·293 | ·586 | ·880 | 1·17 | 1·47 | 1·76 | 2·05 | 2·34 | 2·64 | 3·03 | 3·52 | 4·40 | 5·36 | 7·33 |
| 11 | ·320 | ·640 | ·960 | 1·28 | 1·60 | 1·92 | 2·24 | 2·55 | 2·88 | 3·20 | 3·84 | 4·80 | 6·40 | 8·00 |
| 12 | ·346 | ·693 | 1·040 | 1·38 | 1·73 | 2·08 | 2·43 | 2·77 | 3·12 | 3·46 | 4·16 | 5·20 | 6·93 | 8·67 |

table should be correspondingly increased. If the traction is just 10 lbs., a car will roll down a one per cent. grade without accelerating its velocity. In fact an experiment of this kind would determine approximately what the traction is.

## Flexible Steel Wire Ropes (Bullivant).

| Size Circumference. | Flexible Steel Wire Rope, 6 Strands, each 12 Wires. | | | Extra Flexible Steel Wire Rope, 6 Strands, each 24 Wires. | | Special Extra Flexible Steel Wire Rope, 6 Strands, each 37 Wires. | | Size Circumference. |
|---|---|---|---|---|---|---|---|---|
| | Approximate Weight per Fathom. | Diameter of Barrel or Sheave round which it may be at a Slow Speed Worked. | Guaranteed Breaking Strain. | Approximate Weight per Fathom. | Guaranteed Breaking Strain. | Approximate Weight per Fathom. | Guaranteed Breaking Strain. | |
| Inches. | Lbs. | Inches. | Tons. | Lbs. | Tons. | Lbs. | Tons. | Ins. |
| 1 | ·63 | 6 | 1¾ | ·88 | 3¼ | — | — | 1 |
| 1¼ | 1·06 | 7½ | 2½ | 1·55 | 5 | — | — | 1¼ |
| 1½ | 1·44 | 9 | 4 | 1·88 | 7½ | 2·0 | 8 | 1½ |
| 1¾ | 2·0 | 10½ | 5½ | 2·68 | 9¾ | 2·88 | 11 | 1¾ |
| 2 | 2·44 | 12 | 7 | 3·78 | 13 | 4·0 | 14½ | 2 |
| 2¼ | 3·37 | 13½ | 9 | 4·75 | 16¼ | 5·2 | 17½ | 2¼ |
| 2½ | 4·19 | 15 | 12 | 5·31 | 20½ | 6·3 | 22 | 2½ |
| 2¾ | 5·25 | 16½ | 15 | 6·12 | 24 | 6·81 | 26½ | 2¾ |
| 3 | 6·25 | 18 | 18 | 8·0 | 28½ | 8·81 | 32¼ | 3 |
| 3¼ | 7·06 | 19½ | 22 | 9·37 | 34 | 10·38 | 36½ | 3¼ |
| 3½ | 8·25 | 21 | 26. | 10·75 | 39 | 11·9 | 43 | 3½ |
| 3¾ | 9·87 | 22½ | 29 | 12·19 | 45½ | 13·5 | 50 | 3¾ |
| 4 | 11·25 | 24 | 33 | 13·62 | 51½ | 15·3 | 56½ | 4 |
| 4¼ | 12·35 | 25½ | 36 | 15·69 | 59 | 17·12 | 65 | 4¼ |
| 4½ | 13·44 | 27 | 39 | 17·75 | 65 | 19·0 | 70½ | 4½ |
| 4¾ | | | | 19·88 | 74 | 21·69 | 79 | 4¾ |
| 5 | | | | 22·5 | 82½ | 24·38 | 88 | 5 |

# Table of Round Steel Wire Ropes for Mining, Hauling, Winding, and Similar Purposes.

Showing the breaking strains obtained from different qualities of Wire Ropes, the weight per fathom being the same for all qualities (Bullivant).

| Size Circumference. | Diameter. | "Crucible" Steel. | Best Selected Improved "Crucible" Steel. | Best Selected "Mild Plough" Steel. | Best Selected "Extra Plough" Steel. | Approximate Weight per Fathom. |
|---|---|---|---|---|---|---|
| Inches. | Inches. | B.S. Tons. | B.S. Tons. | B.S. Tons. | B.S. Tons. | Lbs. |
| 1¼ | $\frac{13}{32}$ | 4½ | 4¾ | 5¼ | 5¾ | 1¾ |
| 1½ | ½ | 6 | 6½ | 7¼ | 7¾ | 2½ |
| 1¾ | $\frac{9}{16}$ | 8¼ | 8¾ | 9½ | 10½ | 3¼ |
| 2¾ | ⅝ | 11 | 11¾ | 12¾ | 14¼ | 4 |
| 2¼ | $\frac{11}{16}$ | 14¼ | 15 | 16½ | 18 | 5¼ |
| 2½ | $\frac{13}{16}$ | 17½ | 18¼ | 20 | 22½ | 6¼ |
| 2¾ | ⅞ | 21¼ | 22½ | 24¾ | 27¼ | 7½ |
| 3 | $\frac{15}{16}$ | 24¾ | 26½ | 29 | 31¾ | 9 |
| 3¼ | 1 | 29¾ | 31¾ | 35 | 38 | 10½ |
| 3½ | $1\frac{1}{16}$ | 34½ | 36¾ | 40¼ | 44¼ | 13 |
| 3¾ | $1\frac{3}{16}$ | 39½ | 42 | 46 | 50¾ | 14½ |
| 4 | 1¼ | 45½ | 48½ | 53 | 58 | 16½ |
| 4¼ | 1⅜ | 52½ | 56 | 61½ | 67 | 17¾ |
| 4½ | $1\frac{7}{16}$ | 57½ | 61 | 67 | 73 | 20 |
| 4¾ | 1½ | 65 | 69 | 76 | 83 | 22 |
| 5 | 1⅜ | 72 | 76 | 83 | 92 | 25 |

The diameter of drums and sheaves should be about thirty times the circumference of the rope.

For shaft winding at high speed one-tenth of the breaking strain of a rope is sometimes taken as a fair working load. For inclines, the proportion of load to breaking strain varies according to gradient conditions, and friction should be allowed for.

## Breaking Strains of Steel Wire (Ryland).

| S.W.G. | Annealed. | Bright. |
|---|---|---|
| | Lbs. | Lbs. |
| 0000000 | 13,611 | 20,310 |
| 000000 | 11,722 | 17,583 |
| 00000 | 10,159 | 15,243 |
| 0000 | 8,712 | 13,067 |
| 000 | 7,534 | 11,302 |
| 00 | 6,593 | 9,891 |
| 0 | 5,726 | 8,573 |
| 1 | 4,901 | 7,351 |
| 2 | 4,127 | 6,221 |
| 3 | 3,458 | 5,187 |
| 4 | 2,930 | 4,395 |
| 5 | 2,447 | 3,672 |
| 6 | 2,007 | 3,011 |
| 7 | 1,668 | 2,530 |
| 8 | 1,393 | 2,091 |
| 9 | 1,130 | 1,694 |
| 10 | 893 | 1,339 |
| 11 | 734 | 1,099 |
| 12 | 590 | 884 |
| 13 | 461 | 691 |
| 14 | 349 | 523 |
| 15 | 284 | 424 |
| 16 | 223 | 334 |
| 17 | 170 | 256 |
| 18 | 128 | 188 |
| 19 | 87 | 130 |
| 20 | 72 | 106 |

## Diameter of Wire-Rope Pulleys.

The following translation of a method for calculating the diameter of wire-rope pulleys, given by H. Blasius in the *Zeitschrift der Vereines deutscher Ingenieure*, Berlin, is taken from the abstracts, *Proceedings of the Institution of Civil Engineers*, vol. cxcvii., p. 350.

Loaded wire-ropes are subject to tensile and to bending stresses. If R be the radius of the pulley, $r$ that of the individual strand (not rope), then the bending stress is—

$$\sigma_b = E\frac{r}{R}.$$

The factor $\frac{3}{8}$, which is often empirically employed, cannot be justified theoretically, and is ignored by the author.

If $i$ be the number of wires in the rope, then the tensile stress may be expressed as—

$$\sigma_r = \frac{P}{i\pi r^2}.$$

Whence the total stress—

$$K_s = \sigma_b + \sigma_r = \frac{Er}{R} + \frac{P}{i\pi r^2}.$$

The author shows that the smallest value of R is obtained by distributing the values as follows:—

$$2r = \sqrt{\frac{12P}{i\pi K_s}},$$

$$2R = \sqrt{\frac{27E^2P}{i\pi K_s^3}},$$

$$\frac{R}{r} = \frac{3E}{2K_s} = \frac{3 \times 22000}{2 \times 40} = 825.$$

*i.e.*, $K_s$ should be distributed in the proportion of 1 : 2 between $\sigma_r$ and $\sigma_b$.

## Tests of Steel Wire Used in Ropes for Aerial Rope-Ways.

J. M. Henderson, A.M.I.C.E.

*Tension.*—Tensile breaking stress, 90 tons to 115 tons per square inch. Patent steel, 90 tons to 100 tons per square inch. Plough steel, 95 tons to 115 tons per square inch.

*Torsion.*—Test length, 8 inches. From 24 turns in largest wires to 40 turns in smallest.

*Bending.*—Bending the wire to a right angle round its own diameter 10 to 15 times.

*Elongation.*—Length of test piece, 1 foot to 2 feet according to testing machine. Elongation of wire under a tensile stress of 90 tons per square inch, 3 per cent. to 5 per cent. The lower elongation in the smallest wires, the higher in the largest wires. The figures also cover the variation between plough steel and patent steel wire.

The following tables, giving particulars of some typical wire rope-ways, compiled by Mr J. M. Henderson, are abstracted from the *Proceedings of the Institution of Civil Engineers*, vol. clviii:—

Wire Rope-Ways on Bridge and Viaduct Construction.

| Name and Location of Bridge or Viaduct. | | Clear Span. | Height of Supports. | | Load. | Engine Cylinders. | | Diameter of Drums. | Ty… Bo… |
|---|---|---|---|---|---|---|---|---|---|
| Name. | Location. | | Head. | Tail. | | Dia. | Stroke. | | |
| | | Feet. | Feet. | Feet. | Tons. | Ins. | Ins. | Ins. | |
| Vauxhall | Westminster | 904 | 76 | 72 | 4 | 11 | 21 | 66 | Ve… |
| Kew Bridge | London | 525 | 60 | 50 | 4 | 10 | 18 | 66 | Lo… |
| Viaduct | Kirkcaldy | 430 | 45 | 35 | 2 | 8 | 12 | 48 | Ve… |
| ,, | Co. Durham | 900 | 62 | 58 | 3 | 8 | 12 | 48 | |
| ,, | ,, | 835 | 60 | 57 | 3 | 8 | 12 | 48 | |
| ,, | Devon. | 1,000 | 72 | 60 | 2½ | 8 | 12 | 48 | |

## Wire Rope-Ways on Dock Works.

| Name and Location of Dock. | | Span. | Height of Supports. | | Load. | Engine Cylinders (two). | | Diameter of Drums. | Type of Boiler. | Capacity per Ten Hours. |
|---|---|---|---|---|---|---|---|---|---|---|
| Name. | Location. | | Head. | Tail. | | Dia. | Stroke. | | | |
| | | Feet. | Feet. | Feet. | Tons. | Ins. | Ins. | Ins. | | Tons. |
| H.M. Dockyard | Malta | 750 | 60 | 50 | 5 | 11 | 18 | 58 | Loco. | 800 |
| H.M. Dockyard | Gibraltar | 655 | 75 | 25 | 4 | 10 | 18 | 58 | Vert. | 840 |
| Hong-Kong - | Hong-Kong | 1,100 | 40 | 40 | 5 | 11 | 18 | 54 | Loco. | 400 |
| Simons Bay - | South Africa | 500 | 55 | 50 | 3 | 8 | 12 | 50 | ,, | 150 |

## Wire Rope-ways at Waterworks.

| Name and Location of Waterworks. | | Type of Rope-way. | Clear Span. | Height of Supports. | | Load. | Engine Cylinders. | | Diameter of Drums. | Type of Boiler. |
|---|---|---|---|---|---|---|---|---|---|---|
| Name. | Location. | | | Head. | Tail. | | Dia. | Stroke. | | |
| | | | Feet. | Feet. | Feet. | Tons. | Ins. | Ins. | Ins. | |
| Edinburgh - | Peeblesshire | Fixed | 1,450 | 28 | 25 | 6 | 11 | 18 | 66 | Loco. |
| Howden Dam | Nr. Sheffield | Two radial | 1,360 | 40<br>50 | 30<br>20 | 6½ | 11 | 18 | 61 | ,, |
| Swansea - | Breconshire | Fixed | 1,250 | 70 | 65 | 4 | 10 | 18 | 61 | ,, |
| Ilkley - | Yorkshire | ,, | 1,000 | 55 | 52 | 3 | 8 | 12 | 50 | Vert. |
| Harrogate - | ,, | Travelling | 1,028 | 60 | 50 | 6½ | 10 | 18 | 61 | Loco. |
| Derwent Dam | Nr. Sheffield | Two radial | 1,520 | 50<br>40 | 30<br>30 | 6½ | 11 | 18 | 61 | ,, |
| Motherwell | Scotland | Fixed | 950 | 35 | 25 | 3½ | 8 | 12 | 50 | Vert. |

## Wire Rope-ways at Factories.

| Name and Location of Works. | | Span. | Height of Supports. | | Load. | Diameter of Drums. | Motive Power. | Capacity per Ten Hours. |
|---|---|---|---|---|---|---|---|---|
| Name. | Location. | | Head. | Tail. | | | | |
| | | Feet. | Feet. | Feet. | Cwt. | Inches. | | Tons. |
| Paper mill - | Sheffield | 220 | Fixed on buildings | | 12 | 39 | Electric | 95 |
| ,, ,, - | Fifeshire | 210 | 20 | 60 | 12 | 39 | ,, | 50 |
| Cotton ,, - | Oldham | 320 | Fixed on buildings | | 7 | 36 | Belt | 30 |
| Biscuit works - | Reading | 260 | Fixed on buildings | 32 | 6 | 36 | ,, | 20 |

## Cost of Wire Rope-Way (Length, 13,320 feet Rise, 3,932 feet), Kotagudi, North Travancore.

(R. F. THORP, M.I.C.E., *Proceedings of the Institution of Civil Engineers*, vol. clxi., p. 342.)

FIRST COST.

| | Rupees. |
|---|---|
| Materials bought locally, including steel for standards, cement roofing, sheets, &c. | 14,500 |
| Transport, 55 miles by cart and coolies | 6,800 |
| Coolie labour, erection, &c. | 26,850 |
| Fitters, blacksmiths, and carpenters | 4,600 |
| Supervision, including office staff and medical charges | 18,200 |
| Bridle track along line of rope-way (5 miles) | 2,700 |
| Old spur wheels, &c. | 1,500 |
| Two dynamos with spare armatures and fittings | 1,300 |
| Copper cable, posts, and erection | 3,000 |
| Two Pelton wheels with valves, &c. | 3,000 |
| Spouting for watercourse | 2,000 |
| Service pipe, 1,500 feet | 7,500 |
| Rope | 12,000 |
| Standard head pulleys and bearings | 1,440 |
| Grips | 3,500 |
| Hangers | 700 |
| Total | 121,290 |

At value of rupee in 1905, £8,086, or say £8,300, including telephones, &c. Maintenance and working expenditure during twelve months were as follows:—

PAY-SHEET.

| | Rupees. |
|---|---|
| Engineer in charge | 3,600 |
| Native clerks (2) | 960 |
| Fitters (4) | 2,736 |
| Coolies (20) | 4,656 |
| *Repairs, Materials, &c.* | |
| New jaws for grips (renewed every four months) | 2,520 |
| Share of new rope (renewed every three years) | 4,000 |
| Standard head rope pulleys and bearings (renewed every four years) | 360 |
| Rope for slings and rope drive | 150 |
| Tools | 100 |

*Oil, Cotton, Waste, &c.*

| | |
|---|---|
| 100 gallons oil - - - - - - - | 150 |
| 25 gallons dynamo oil - - . - - | 75 |
| Waste, &c. - - - - - - - - | 50 |
| | 19,357 |
| Contingencies and depreciation of plant - - - | 2,535 |
| 5 per cent. interest on first cost (£8,300) - - - | 6,225 |
| Total annual expenditure - - | 28,117 |

Say, £1,874. 9s. 4d.

## List of Papers, Articles, &c., Describing Wire Rope-Ways, 1899-1917.

"Aerial Rope-Ways," E. Sobo. Berg- und Hüttenmännische, Jahrbuch der K. K. Bergakademien, 1899, p. 369-469 (136 illustrations).

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"Mechanical Equipment Used in the Port of New Orleans," W. von Phul. *Journal of the American Society of Mechanical Engineers*, New York, 1916, vol. 38, pp. 515-528.

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